ECONOMIC ASSESSMENT OF THE ATLANTIC COAST HORSESHOE CRAB FISHERY

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PURPOSE OF THE REPORT

In this report, Industrial Economics, Incorporated (IEc) provides an assessment of the economic value of the Atlantic Coast horseshoe crab fishery. We accomplish this by examining the economic importance of this unique fishery to three diverse industries and user groups: wildlife viewing/birding enthusiasts, the biomedical industry, and the Atlantic Coast commercial eel and conch pot fisheries.

We analyze the economic importance of these industries and groups using two analytical approaches. First, we quantify net changes in economic well-being, using standard methods of welfare economics. Second, we consider the regional economic importance of the horseshoe crab using a commonly applied input-output model. The two measures of economic value we develop are quite different, but equally valid. Net social welfare estimates provide one measure of economic value, that is, the economic "surpluses" generated through the provision of a good or service. Regional economic analyses consider the ways in which an industry creates economic relationships with other entities -- "upstream" and "downstream" businesses, employees, and others -- within the region where it resides.

With this assessment, the U.S. Fish and Wildlife Service (FWS) seeks to improve upon current understanding of the economic importance of the Atlantic Coast horseshoe crab population. There is mounting concern that this resource suffers from overexploitation. Numerous articles have appeared in the popular press which describe one or more reasons for renewed interest in the horseshoe crab.[1] However, to date, no assessment has provided reliable estimates of the economic value of this resource, nor has any assessment accurately characterized the economic influence of related industries/user groups on locales that have come to trust in the availability of this resource. We recognize that the influence of any one of these industries on the economy *at-large* is practically negligible. To many of the local economies that depend on these industries for jobs and local spending, however, their contributions may be significant.

[1] See, for example: Braile, Robert. "Vital to many, horseshoe crab in danger," Boston Globe, November 9, 1999.

SUMMARY OF FINDINGS

In this chapter, we describe the national and regional economic relevance of the three industries/user groups that rely on the Atlantic Coast horseshoe crab. Exhibit 1-1 summarizes these findings.

Economic Contribution of Wildlife Viewing/Birding

Each spring, thousands of migratory shorebirds stop in Delaware Bay during their annual fly-over to Arctic breeding grounds to feed on the eggs of spawning horseshoe crabs. The ecological importance of this event is still poorly understood -- researchers are currently exploring whether the horseshoe crab spawning event is critical to the viability of these bird populations. A related issue is whether bird populations have enhanced reproductive success as a result of feeding on horseshoe crab eggs. Despite these ecological uncertainties, thousands of birders are clearly congregating at beaches and viewing areas along Delaware Bay each spring for the primary purpose of witnessing this phenomenon.

As noted above, we also consider the regional economic importance of the horseshoe crab. The economy of the Cape May region accrues specific benefits, in part, because birders' purchases of recreation-related goods and services (e.g., food, lodging, equipment) are highly localized during this event. As shown in Exhibit 1-4, our analysis indicates that annual economic activity in the Cape May region associated

MEASURING NET SOCIAL WELFARE AND REGIONAL ECONOMIC IMPACTS

Welfare economics is based upon the idea that social welfare can be maximized by using resources in ways that yield the greatest benefits to society. Economists generally rely on consumer surplus as a measure of net social welfare. Consumer surplus is based on the principle that some consumers benefit because they are able to purchase goods or services at a price that is less than their total willingness to pay (i.e., the maximum amount they would pay for a good). That is, consumers receive utility that exceeds the price they pay for the good.

In the context of this study, consumer surplus is realized in several ways. First, birders realize consumer surplus when the value of their bird viewing experience exceeds the "price" they pay for the experience, in terms of travel costs, equipment costs, and park fees. Similarly, in the biomedical and commercial fishing industries, consumer surplus is realized in markets for LAL and shellfish (eel and whelk) because consumers pay less for these products than their total willingness to pay for them. Since the horseshoe crab serves as a critical input to both of these industries, it is thereby credited with creating the consumer surplus that accrues in both end-product markets.

Regional economic analyses measure economic activities differently than welfare economics, by focusing on the economic influence of an industry in a particular geographic region. These analyses recognize the interconnections that exist between an industry, the local businesses that supply it, its employees and the employees of its suppliers. Thus, they demonstrate that industries create effects which resonate throughout the local economies in which they reside.

Input-output models (like the one employed in this analysis) are the standard tool for conducting regional economic analyses. These models calculate regional impacts through the use of "multipliers," or values which describe the magnitude of an industry's influence on regional output and employment. A multiplier of 1.8 for the biomedical industry, for example, indicates that for every $1 of output generated by a biomedical firm, $1.8 is created in total via this firm's linkages to other business entities in the region.

A key limitation of input-output models is that they provide only static "snapshots" of an economy, and thus do not account for dynamic responses that actually occur (i.e., adjustments that take place over time). This is best illustrated through an example. If the biomedical firm relocates to another region, an input-output model will show that all jobs associated with the firm leave the region. In reality, many of the firm's employees would stay in the region and find other jobs, depending on their skills and available positions. Similarly, firms that supply goods and services to that firm will seek out other markets. Thus, actual net changes in output and employment are usually smaller than those suggested by results from input-output models.

with spending on horseshoe crab-dependent eco-tourism ranges from about $7 million to $10 million (1999 dollars). Of this total, compensation received by employees in the eco-tourism industry (and related industries) accounts for about $2 million to $3 million. Exhibit 1-5 shows that approximately 120 to 180 jobs are also associated with these industries.

Results from a 1999 survey of birders visiting the Cape May, New Jersey region to view the horseshoe crab/migratory shorebird event provide the basis for our social welfare valuation of these primary purpose trips. Based on an estimate of birders' average "willingness-to-pay" (i.e., the amount beyond what birders are actually required to spend to witness the event) and an estimate of the number of days spent by birders at this event, we calculate an annual social welfare value of $3 million to $4 million in 1999 dollars (as shown in Exhibit 1-2).

Economic Contribution of the Biomedical (LAL) Industry

The biomedical industry produces a valuable substance known as *limulus ameboecyte lysate* (LAL) from the blood of horseshoe crabs. This substance provides the pharmaceutical industry with a sensitive agent for testing a variety of biomedical products and injectable drugs (e.g., vaccines) for the presence of hazardous endotoxins. Three U.S. firms dominate the world market for LAL, which generates annual revenues of $60 million.

These three firms generate regional spending in the locales where they reside: Falmouth, Massachusetts; Walkersville, Maryland; and Charleston, South Carolina. Results from the regional economic analysis find that the LAL industry's contributions to each of these regional economies range from $22 million to $35 million, or $73 to $96 million in total. Moreover, the industry creates approximately 145 to 195 jobs in each region, or about 440 to 540 jobs in total.

Our analysis finds that the LAL industry generates a substantial annual social welfare benefit of at least $150 million (1999 dollars). This estimate of the social welfare benefits of LAL production is driven by the assumption that demand for LAL is relatively *inelastic*, thereby producing large amounts of consumer surplus. We identify two key factors that account for this inelasticity.

- **U.S. Food and Drug Administration (FDA) regulations:** FDA requires that pharmaceutical and biomedical manufacturers use LAL to test end-products for endotoxin before releasing them to the market, thereby assuring that short-run demand for LAL will remain relatively firm in the event of a price increase.

- **Absence of viable substitutes:** In the U.S., end-product testing with LAL has replaced its predecessor, the rabbit fever test, as the industry standard. Alternative tests are currently under research and development, but are probably five to ten years from being commercially available.

Economic Contribution of Commercial Fishing

Commercial whelk and American eel pot fisherman along the Atlantic coast use the horseshoe crab as one of their primary baits. Due to a scarcity of reliable economic data describing these unique pot fisheries, we rely on best industry judgment to develop estimates of market supply and demand in these fisheries.

Exhibits 1-4 and 1-5 show the regional economic contributions of these fisheries, in terms of output and jobs. The whelk pot fishery contributes $11 to $15 million in annual output, as well as 270 to 370 jobs. Whelk potting in Virginia accounts for the majority of this contribution, as restrictions on horseshoe crab landings in the Mid-Atlantic have caused this fishery to migrate southward. The eel pot fishery creates approximately $2 million and 70 jobs in the regions where this fishery is active. Again, much of this economic activity takes place in Virginia, and also in the Mid-Atlantic (New Jersey, Delaware, and Maryland).

In response to recent demand and the collapse of other fisheries, the commercial whelk market has emerged within the last ten years. Using horseshoe crab landings data, bait requirements, and other information, we estimate the social welfare value of the whelk pot fishery to be approximately $9 million (1999 dollars). A key qualitative assumption is that whelk occupies the lower end of the shellfish market; thus, most consumers opt for substitutes (e.g., squid) if the price of whelk increases, limiting the consumer surplus associated with this market.

Eel pot fishermen do not rely on horseshoe crab for bait as extensively as those in the whelk pot fishery, since they find alternative baits (e.g., surf clams) to be effective. We estimate the annual social welfare value of the portion of the eel market that relies on the horseshoe crabs to be almost $6 million (1999 dollars). This estimate includes the value of eel sold as bait to the recreational striped bass fishery. Demand for eel from this market is relatively inelastic, since it constitutes a small cost in recreational anglers' overall expenditures. While we cannot quantify the value of eel sold in retail markets for human consumption, qualitative information on this market suggest that its value is less than the striped bass bait market. Thus, we estimate the total annual economic welfare value of this fishery to be approximately $12 million, and the total value of the conch and eel pot fisheries together to be about $21 million (shown in Exhibit 1-1).

Exhibit 1-1

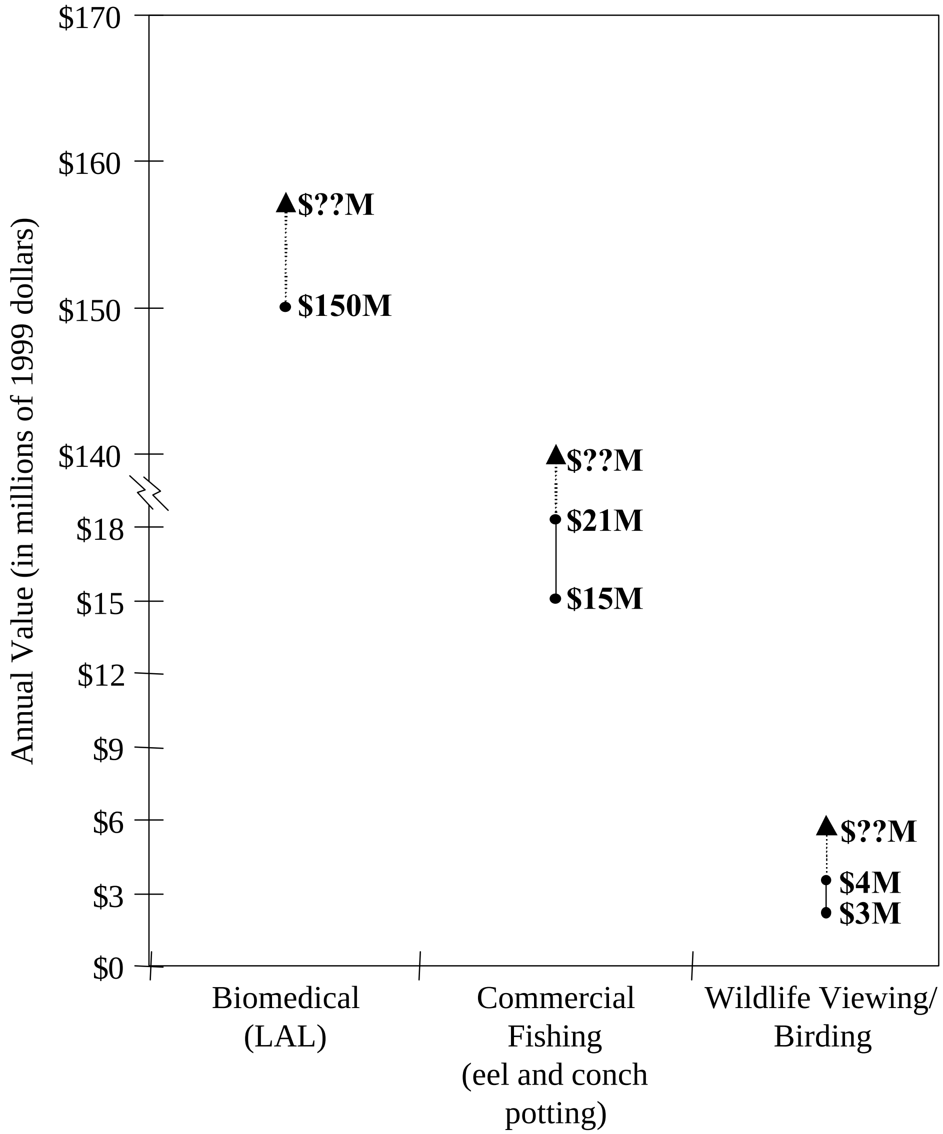
SUMMARY OF RESULTS[a]

Industry/User Group	Regional Economic Contributions: Regional Output (millions of 1999 dollars)	Jobs	Affected Regions	National Economic Welfare Contributions[b] (millions of 1999 dollars)
WildlifeViewing/ Birding	$7 to $10	120 to 180	-- New Jersey (Cape May, Cumberland Counties)	$3 to $4+
Biomedical (LAL) Industry	$73 to $96	440 to 540	-- Massachusetts (Barnstable, Plymouth) -- Maryland (Howard, Montgomery) -- South Carolina (Charleston, Colleton)	$150+
Whelk Pot Fishery	$11 to $15	270 to 370	-- Massachusetts (Barnstable, Plymouth, Dukes) -- Rhode Island (Washington, Kent) -- Connecticut (New London) -- New York (Suffolk) -- New Jersey (Cape May, Cumberland) -- Delaware (Kent, Sussex) -- Maryland (Worcester) -- Virginia (Accomack, Northampton, and Hampton)	$9
Eel Pot Fishery	$2	70	-- Massachusetts (Essex) -- Rhode Island (Kent) -- Connecticut (Middlesex) -- New York (Suffolk County) -- New Jersey (Cumberland, Burlington) -- Delaware (Kent, Sussex) -- Maryland (Somerset, Wicomico) -- Virginia (Westmoreland, Middlesex, Gloucester) -- Florida (Clay, Putman)	Striped bass bait market: $6+; Consumption market: not quantified, but less than $6.
TOTALS	**$93 to $123**	**900 to 1,160**		**$175 +**

[a] Estimates presented here have been rounded to reflect a level of precision most appropriate to a summary of key results (i.e., nearest million). We provide more detailed model results, not rounded, throughout the remainder of this report.

[b] Where we believe our estimate represents a lower-bound minimum, we express estimate as $X“+”.

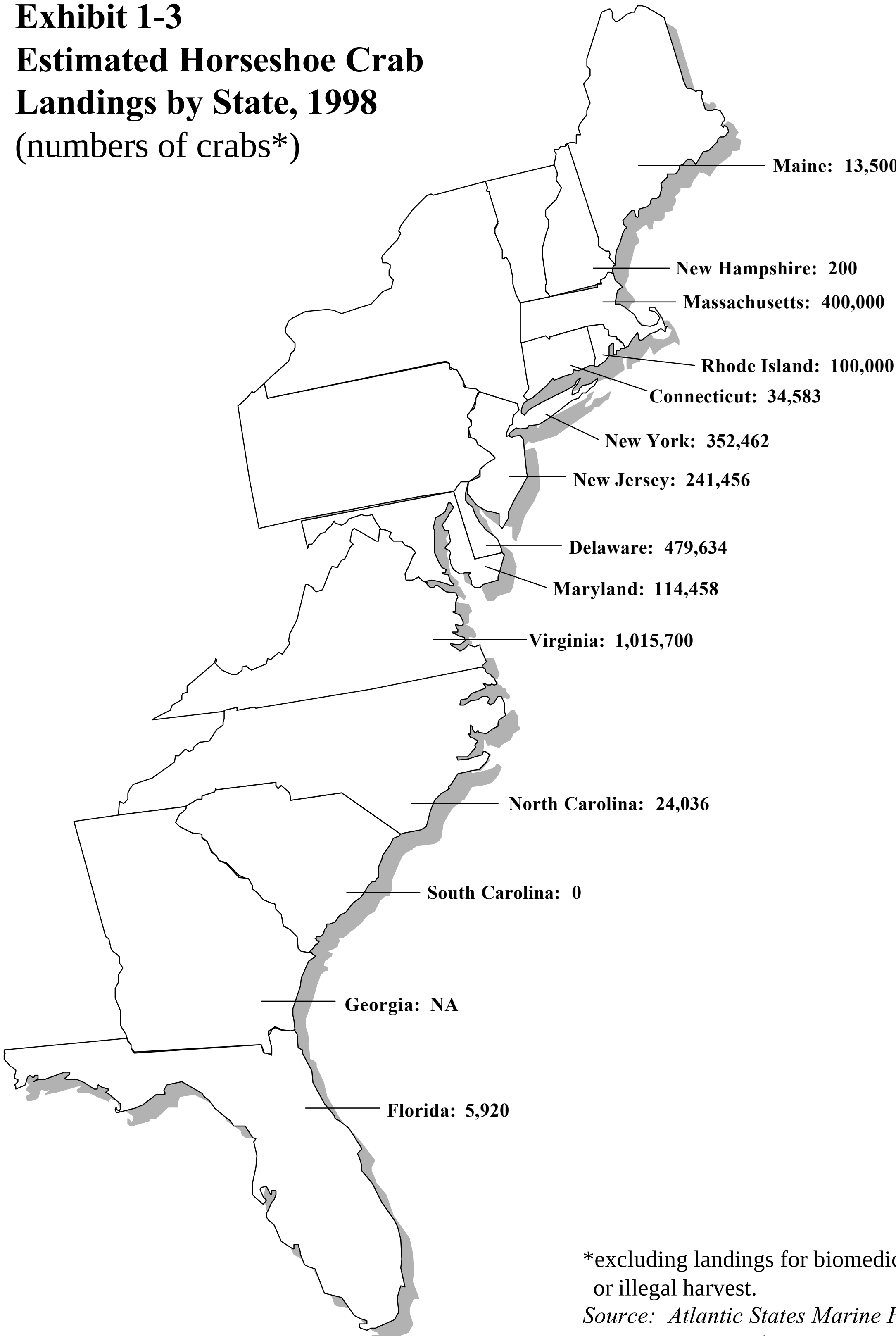
Exhibit 1-2
ANNUAL ECONOMICE WELFARE CONTRIBUTION OF THE HORSESHOE CRAB-DEPENDENT INDUSTRIES



Source: IEc analysis.

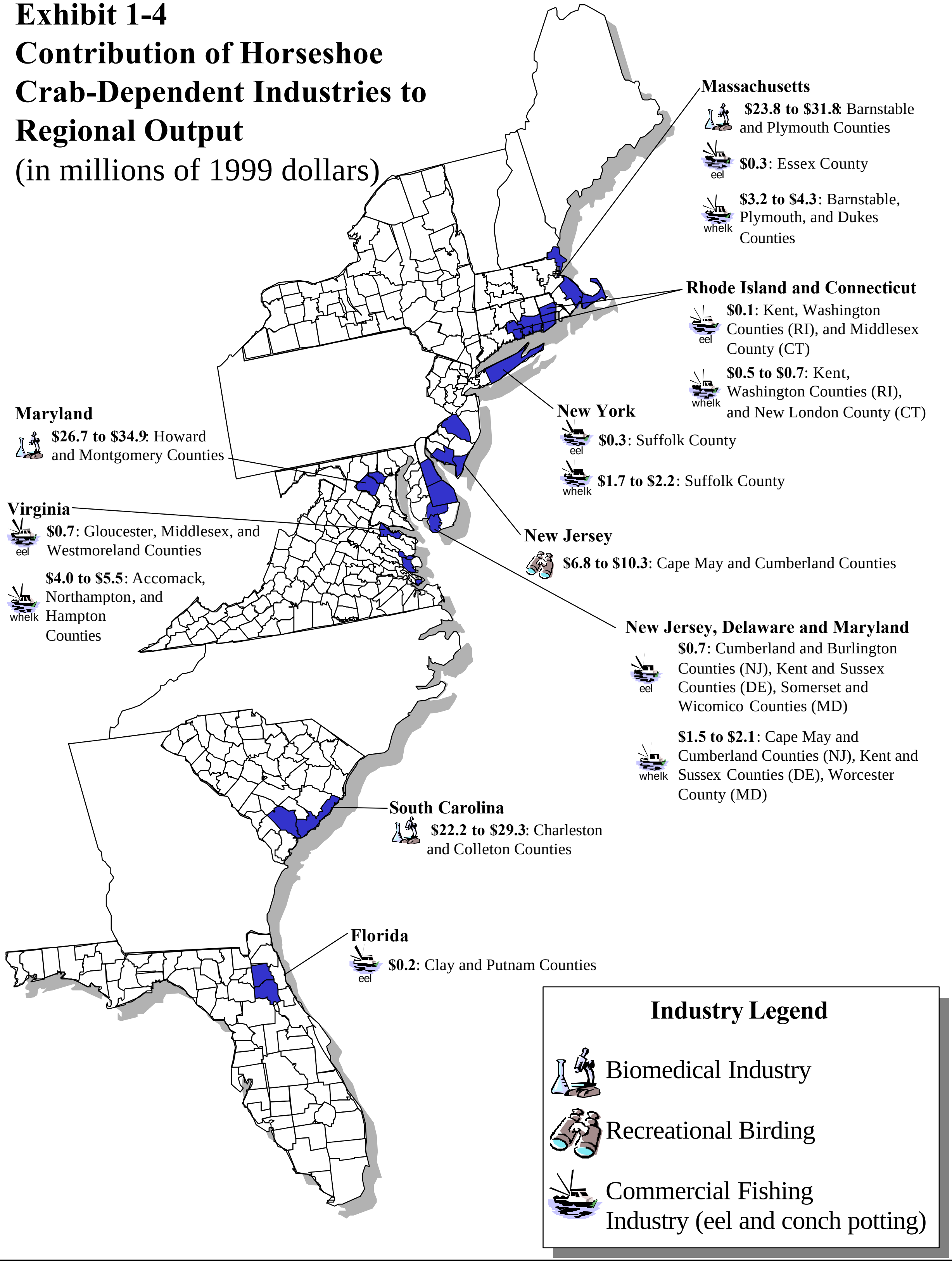
Notes: (1) Estimates for biomedical do not include a quantitative estimate for producer surplus, but we believe it to be less significant than consumer surplus.
(2) Estimates for commercial fishing do not include the value of the eel consumption market, which is addressed qualitatively in this analysis. However, we believe that the value of the eel consumption market is less than the value of the bait market for eel, or $5.7M.
(3) Value of wildlife viewing/birding is likely to be higher than $3.9M if eco-tourism "events" related to the horseshoe crab are taking place in other areas.

Exhibit 1-3
Estimated Horseshoe Crab Landings by State, 1998
(numbers of crabs*)



*excluding landings for biomedical purposes, or illegal harvest.
Source: Atlantic States Marine Fisheries Commission, October 1999.

Exhibit 1-4
Contribution of Horseshoe Crab-Dependent Industries to Regional Output
(in millions of 1999 dollars)



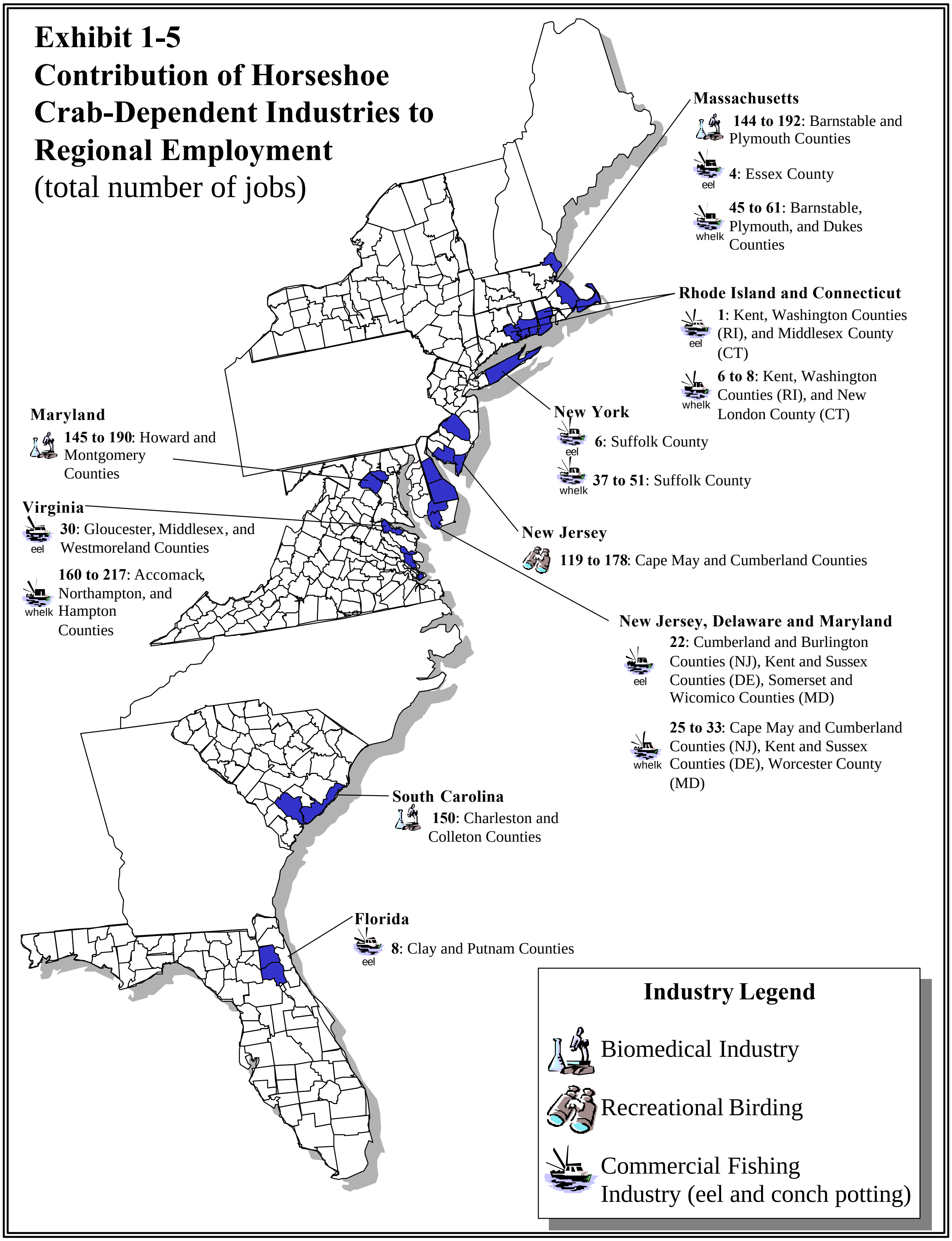


Exhibit 1-5
Contribution of Horseshoe Crab-Dependent Industries to Regional Employment
(total number of jobs)
Massachusetts
144 to 192: Barnstable and Plymouth Counties
eel
4: Essex County
whelk
45 to 61: Barnstable, Plymouth, and Dukes Counties
Rhode Island and Connecticut
eel
1: Kent, Washington Counties (RI), and Middlesex County (CT)
whelk
6 to 8: Kent, Washington Counties (RI), and New London County (CT)
New York
eel
6: Suffolk County
whelk
37 to 51: Suffolk County
Maryland
145 to 190: Howard and Montgomery Counties
Virginia
eel
30: Gloucester, Middlesex, and Westmoreland Counties
whelk
160 to 217: Accomack, Northampton, and Hampton Counties
New Jersey
119 to 178: Cape May and Cumberland Counties
New Jersey, Delaware and Maryland
eel
22: Cumberland and Burlington Counties (NJ), Kent and Sussex Counties (DE), Somerset and Wicomico Counties (MD)
whelk
25 to 33: Cape May and Cumberland Counties (NJ), Kent and Sussex Counties (DE), Worcester County (MD)
South Carolina
150: Charleston and Colleton Counties
Florida
eel
8: Clay and Putnam Counties
Industry Legend
Biomedical Industry
Recreational Birding
Commercial Fishing Industry (eel and conch potting)

LIMITATIONS OF THE ANALYSIS

It is important to highlight several limitations associated with both the net social welfare and regional economic analyses described in this report. First and foremost, reliable market data do not exist for the horseshoe crab. Instead, we rely upon the validity and soundness of the professional judgement of industry experts. To the extent that these judgements differ from actual market conditions, some error may be present in our estimates.

With respect to our estimate of the value of horseshoe crab-dependent wildlife viewing/birding, we note that the annual Cape May event may be but one of many eco-tourism activities occurring during horseshoe crab spawning season. In addition, the horseshoe crab may contribute to birding activities elsewhere along the Atlantic Coast, and at other times during the year. Thus, the estimates presented in this report should be considered a lower-bound for the actual value of horseshoe crab-dependent eco-tourism.

Finally, there are some caveats to our application of the IMPLAN model, which we use to generate regional economic results. First, IMPLAN is not a dynamic modeling tool, and thus does not account for adjustments that take place over time. Thus, actual net changes in output and employment that would result from limits on harvest of horseshoe crabs would be smaller than those implied by the model results we present. Another limitation of the IMPLAN model is its reliance on 1994 economic data. In light of the rate of economic growth in the last five years, these data are likely to markedly understate the level of baseline economic activity in all regions, particularly in fast-growing coastal regions.

We find that our regional economic results, when expressed in relative terms (e.g., as a percentage of baseline activity), are sensitive to the definition of the *study area* (i.e., the localities that make up each region). For all industries modeled, relative regional contributions to output and employment change significantly if key counties are included (or excluded) from the model. This is to be expected, given the proximity of many of these counties to the coast, where economic growth far exceeds the national average. We feel the study areas chosen for this regional economic analysis, however, best represent actual interdependencies that exist in these economies.

ORGANIZATION OF THE REPORT

The remaining chapters of this report are organized as follows:

- In Chapter 2, we provide an overview of the Atlantic Coast horseshoe crab population, as well as a description of the industries and user groups dependent upon the horseshoe crab.

- In Chapter 3, we provide estimated 1998 horseshoe crab landings for each Atlantic state. In addition, we describe the data sources used to generate these estimates and highlight recent trends reflected in the data, including geographic shifts in horseshoe crab landings.

- In Chapter 4, we discuss the net economic welfare generated by the horseshoe crab population. Specifically, we examine the contributions of the industries and user groups dependent upon the horseshoe crab to national well-being, as reflected in the producer and consumer surplus.

- In Chapter 5, we present our analysis of the horseshoe crab’s contributions to specific regional economies, expressed in terms of economic output and jobs. We also compare these contributions relative to the baseline level of economic activity taking place in each region.

In this chapter we describe the key characteristics of the Atlantic coast horseshoe crab population. In addition, we provide an overview of the industries and user groups that rely upon the horseshoe crab and describe the economic contribution of each industry/user group.

THE ATLANTIC COAST HORSESHOE CRAB POPULATION

Along the Atlantic coast, the horseshoe crab (*Limulus polyphemus)* is found in estuary and bay bottoms and near-shore continental shelf habitats. These creatures, not true crustaceans but members of the arthropod family, are ecological generalists which thrive in a wide range of environmental conditions. Thus, major evolutionary changes in *L. polyphemus* have been strikingly few in over 350 million years of existence.[2]

Concern that the Atlantic coast horseshoe crab population is being overexploited has led to research on the life history, habitat requirements, and population dynamics of this species.[3] To date, these factors and the overall health of the population have been poorly understood. It is certain, however, that the range of the horseshoe crab spans broadly from the Yucatan peninsula to the northern Maine coast, with population densities highest in estuaries between Virginia and

[2] Atlantic States Marine Fisheries Commission, 1998.

[3] For more information on these and other characteristics of the Atlantic coast horseshoe crab population, refer to: (1) Botton, M.L and J.W. Ropes. 1987. "The horseshoe crab, *Limulus polyphemus*, fishery and resource in the United States," *Marine Fisheries Review* 85 (4): 805-812; (2) Shuster, C.N., Jr. 1950. Observations on the natural history of the American horseshoe crab, *Limulus polyphemus*. 3rd rept., Investigations of Methods of Improving the Shellfish Resources of Massachusetts, Woods Hole Oceanographic Institution; and (3) Shuster, C.N., Jr. and M.L. Botton. 1985. "A contribution to the population biology of horseshoe crabs, *Limulus polyphemus* (L.), in Delaware Bay," *Estuaries* 8(4): 363-372.

New Jersey. Scientists believe that the population of horseshoe crabs spawning on the intertidal beaches of the Delaware Bay region is among the world's largest, but many observers feel this population has suffered a serious decline in recent years due to human influence.[4]

In the late 1800s and early 1900s, horseshoe crabs were harvested by the millions to be ground into fertilizers or used as livestock feed.[5] Current human uses of the horseshoe crab support both recreational and commercial activities. In this chapter, we describe the industries and recreational user groups that depend on the Atlantic Coast horseshoe crab. In addition, we describe the economic value created by each of these industries/user groups.

CURRENT USES OF THE HORSESHOE CRAB

The Atlantic Coast horseshoe crab is a genuine "multiple-use" resource, as there are three distinct groups that depend on and/or utilize the horseshoe crab (albeit in very different ways). Below we describe the economic relevance of each industry and group.

Wildlife Viewing/Birding

For a period of brief duration each spring (from mid-May through early June), millions of migratory shorebirds converge on Cape May and neighboring Delaware Bay beaches during their stop-over from wintering grounds in South America to breeding grounds in the Arctic.[6] These shorebirds, which include red knots (*Calidris canutus*), ruddy turnstones (*Arenaria interpres*), semipalmated plovers (*Charadrius semipalmatus*) and sanderlings (*Calidris alba*), feed on eggs deposited under a layer of sand by spawning horseshoe crabs and thereby replenish depleted fat stores before continuing on their northward migration.[7]

Results of early studies of this annual phenomenon suggest that the Delaware Bay stop-over may be essential for these bird populations to meet basic requirements for rest and energy before attempting the final leg of a journey to the Arctic region.[8] However, there still exists substantial ecological uncertainty regarding the importance of the horseshoe crab population. Specifically, scientists remain uncertain whether the presence of horseshoe crab eggs is essential

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[4] Recent studies indicate that Delaware Bay crab populations may have declined by as much as 50 percent since 1990 (Harrington and Shuster, 1999).

[5] Op. cit, p. 3.

[6] Atlantic States Marine Fisheries Commission (1998); Baker *et al.* (1998); Piersma *et al.* (1998).

[7] Due to the very high fat content of horseshoe crab eggs, in some instances shorebirds can add up to 50 percent of their original body weight (Berkson and Schuster, 1999).

[8] Piersma *et al.* (1998); Clark *et al.* (1993); and Myers *et al.* (1987).

to the viability of shorebird populations, or whether these populations would find substitute food sources if horseshoe crab eggs became unavailable. In addition, little evidence exists indicating whether shorebirds which feed on horseshoe eggs have greater reproductive success as a result.

Although our understanding of this relationship is limited, the interaction between horseshoe crabs and migratory shorebirds along Delaware Bay has become a major attraction for recreational birdwatchers in the last decade, and it has thereby created real economic value. Results of a 1999 study by Eubanks et al. describe the relative satisfaction of birders who experienced the horseshoe crab/shorebird event at various beaches in New Jersey.[9] Overall, surveyed birders stated that they found the viewing experience during this event to be unique and high in quality. Moreover, this opinion is reflected by both birders' actual expenditures (on food, lodging, and birding equipment) and by their stated willingness to pay above and beyond their trip expenditures to experience this event. Finally, the regional economy of Cape May, New Jersey has specifically benefited from the horseshoe crab/shorebird event, as many birders use this area as a base for their viewing activities. In Chapters 4 and 5 of this report, respectively, we evaluate the national social welfare benefits of the Delaware Bay horseshoe crab/shorebird event and quantify the contribution of the event to the economy of the Cape May region.

It is possible that other regions (in addition to the Cape May side of Delaware Bay) are experiencing an increase in eco-tourism activity due to the presence of a local horseshoe crab population. In Port Mahon, Delaware, for example, recreational birders are concentrating to view shorebirds during migration, which partially coincides with timing of the local horseshoe crab spawning.[10] In other areas, such as South Carolina, horseshoe crabs may themselves add an interesting facet to eco-tourism (e.g., tours focused on marine resources). As little or no quantitative or qualitative information exists describing these activities' relationship to the horseshoe crab, we address them only qualitatively in this assessment. However, we recognize that the quantitative estimates presented herein for wildlife viewing/birding represent the lower-bound minimum of the total economic benefit derived from horseshoe crab-related eco-tourism.

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[9] Eubanks, T., J. Stoll, and P. Kerlinger. 2000. Wildlife-associated Recreation on the New Jersey Delaware Bayshore. Report prepared by Fermata, Incorporated (Austin, Texas) for the New Jersey Department of Fish and Wildlife.

[10] Based on personal communication with Alice Doolittle, Delaware Division of Fish and Wildlife.

Biomedical (LAL) Industry

The discovery that horseshoe crab blood possesses unique clotting properties in the presence of certain pathogens enabled the development of the LAL industry.[11] Using blood from 200,000 to 250,000 adult horseshoe crabs each year as a primary input, this niche biomedical industry produces *Limulus ameboecyte lysate* (LAL), a substance which shows unusual sensitivity to bacterial pathogens known as endotoxins.[12] In 1979, the U.S. Food and Drug Administration (FDA) established requirements for the pharmaceutical industry's use of LAL to test injectable drugs and intravenous devices (e.g., catheters) for endotoxin contamination. Today, all such products released to the U.S. market are screened for endotoxins with LAL, now considered the established standard for this type of testing.

Researchers are currently developing and testing alternative substances for endotoxin screening that are not derived from horseshoe crab blood, but at present no other procedure or substance provides as much accuracy or sensitivity as LAL-based testing.[13] Experts predict a commercially viable substitute for LAL may be developed in five to ten years, but also note that pharmaceutical firms would incur costs to switch from current LAL-based testing protocols approved by FDA to non-LAL tests. In the interim, the global market for LAL grows by about eight to ten percent annually.[14] Demand from overseas markets drives much of this growth, as foreign firms that hope to export biomedical products to the U.S. market must test end-products with LAL in accordance with FDA's requirements.

Commercial Fishing

Two commercial fisheries rely on the horseshoe crab as an important bait, the whelk fishery and the American eel fishery. In both industries, fishermen use horseshoe crabs as bait when potting. The characteristics of each fishery, as well as fishermens' preferences toward the use of horseshoe crabs as bait, vary such that we address each fishery separately in this analysis.

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[11] For more information on the development of the LAL industry, see: (1) Cohen et al. (eds.), 1979. Biomedical Applications of the Horseshoe Crab (Limulidae), Alan Liss, Inc: New York, NY; and (2) Novitsky, T.J. 1984. "Discovery to commercialization: The blood of the horseshoe crab," *Oceanus* 27: 13-18.

[12]Endotoxins are bacterial by-products that form from the cell wall of gram-negative bacteria such as *E. coli* and *salmonella* (Dawson, 1999; McCormick, 1999; Guittierez, 1999).

[13] Based on communication with Dr. Alberto Guitierrez, Center for Biologics Evaluation and Research, U.S. FDA (December 1999).

[14] Demand from Europe, where requirements for end-product testing of pharmaceuticals are similar to those in the U.S., historically has accounted for most of overseas demand. As pharmaceutical sectors in developing countries are established industry experts expect that demand from these areas will account for a greater portion of total overseas demand.

Whelk Pot Fishery

The Atlantic Coast whelk fishery of relevance to this analysis refers to the commercial catch of two principal species, the knobbed whelk (*Busycon carica)* and the channeled whelk (*Busycon canaliculatum*).[15] Both species are gastropods found in temperate waters from Massachusetts to Florida. Ranging in length from seven to 15 inches, both species are carnivorous and rely on an extensible proboscis and muscular foot to hold and consume prey.[16] Whelk may be caught by potting or trawling/dredging along the ocean floor. As trawling/dredging for whelk does not require a bait source, we exclude from our analysis that portion of the whelk fishery attributable to trawl or dredge landings.

The commercial whelk pot fishery along the Atlantic Coast runs from Massachusetts to the Carolinas. Whelk meat is sold for consumption and commonly eaten with salads, sauces, or pasta.[17] At present, the primary markets for whelk include domestic (primarily ethnic market) demand, and international demand from Asia. According to whelk pot fishermen and industry contacts, the use of horseshoe crabs as bait yields substantially higher quantities of whelk than other baits. As a result, fishermen identify horseshoe crabs as the preferred bait for whelk potting and indicate that other baits are rarely used. At present, the use of horseshoe crabs as bait reportedly accounts for approximately 97 percent of total whelk pot landings.

Fishermen along the Atlantic Coast use both male and female horseshoe crabs to attract whelk, although industry contacts report that female crabs yield better results.[18] The quantity of horseshoe crab used for baiting a whelk pot varies by region, season, water temperature, and availability of horseshoe crabs. On average, however, one female horseshoe crab, which is larger than a male, provides bait for one to four whelk pots. By contrast, the average male may provide bait for one to two pots.[19] Experimentation in recent years has led to the development of methods of bait extension, including bait bags, which protect the horseshoe crab bait from other ocean predators, and bait extenders, which combine a small piece of horseshoe crab with a large piece of bait filler commonly referred to as a "binder." While these methods have proven successful in isolated circumstances, they are not yet used or available on a wide-spread scale.

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[15] While the knobbed and channeled whelk caught along the Atlantic coast are commonly referred to as "conch" in general usage as well as in industry transactions, we maintain use of the term whelk in this report for technical accuracy.

[16] The Assateague Naturalist. *www.assateague.com/shells.html*

[17] While the whelk pot fishery in the southern states includes landings of channeled and knobbed whelk, the fishery in the northern states (New York, Connecticut, Rhode Island, and Massachusetts) includes only the channeled whelk. Fishermen report that the knobbed whelk has yet to be successfully potted in northern waters. While the species inhabits northern waters, its potting habits are believed to be extremely sensitive to water temperatures.

[18] Personal communication with fishermen in New Jersey, New York, and Virginia.

[19] Personal communication with fishermen and state contacts in Delaware and Massachusetts.

Eel Pot Fishery

The second commercial fishery we address in this analysis is the American eel (*Anguilla rostrata*). The American eel is a catadromous fish that initiates its life cycle in the Sargasso Sea, travels north to coastal Atlantic waters and freshwater tributaries in its adolescence, remains in coastal watersheds through sexual maturation, and returns once again to the Sargasso Sea at sexual maturity to spawn and die.[20] Commercial fishing of American eel occurs at all life-stages, including young glass eels, elvers, juvenile yellow eels, and adult silver eels. However, as glass eels and elvers are too young to be caught in a pot and silver eels undergo a metamorphosis after which feeding stops (due to a fatty build-up in the body and a degeneration of the digestive tract), the primary life-stage during which potting occurs is the yellow eel phase.[21] Commercial fishermen catching eels during other life-stages rely on the use of small and large nets. As a result, in this report we only examine the portion of the fishery attributable to potting.

Commercial eel potting is reported in every coastal state from Maine to Florida. Potted eel is sold for both consumption and as bait, and markets for the product exist domestically and internationally. Most eel potting occurs in freshwater tributaries, and fishermen often catch eels as they migrate up coastal waterways. According to industry contacts, horseshoe crabs are a popular bait for eel potting. In contrast to the whelk pot fishery, however, the use of horseshoe crab as bait in eel potting varies regionally. In some regions, horseshoe crabs are the preferred bait source, while in others horseshoe crabs are one of several viable bait options. Fishermen report the use of only female horseshoe crabs in potting for eels. As in the whelk pot fishery, the female crabs may be cut into halves, thirds, or quarters for use in baiting eel pots.

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[20] Massachusetts Division of Marine Fisheries & University of Massachusetts Cooperative Extension, (1998).

[21] Personal communication with Vic Vecchio, New York Department of Environmental Conservation, February 2000. According to Julie Weeder at the Maryland Department of Natural Resources, the transformation from yellow eel to silver may occur gradually or vary in length regionally. As a result, industry contacts report that many eels technically classified as silver eels are able to be caught in pots. In addition, fishermen report that some eels caught in pots are unable to be accurately assigned to one life-stage due to the extended transformation process.

ATLANTIC COAST HORSESHOE CRAB LANDINGS CHAPTER 3

In this chapter we examine commercial horseshoe crab landings along the Atlantic Coast. We discuss recent trends in the Atlantic Coast horseshoe crab harvest, and provide current estimates of commercial horseshoe crab landings by state.

AVAILABLE INFORMATION ON HORSESHOE CRAB LANDINGS

In recent years, state and federal fisheries management agencies and conservation organizations have expressed concern about the increasing commercial harvest of horseshoe crabs. These increases are largely attributed to growing demand for horseshoe crabs as bait in the whelk and eel pot fisheries. Biomedical firms that rely on horseshoe crab blood constitute another, significantly smaller component of demand. Prior to the late 1980s and early 1990s, little was known about the commercial harvest of the horseshoe crab along the Atlantic Coast. To address this lack of information, many states have initiated programs to better estimate and monitor the quantity of horseshoe crabs landed.

At present, regulations regarding the commercial harvest of horseshoe crabs vary significantly from state to state. Permits are required for the commercial sale of horseshoe crabs in most, but not all, coastal Atlantic states. In the Mid-Atlantic region, New Jersey, Delaware, and Maryland maintain the strictest regulatory controls, with requirements both for permitting and mandatory reporting, as well as specific restrictions on the location and timing of allowable crab harvesting.

Commercial harvesters currently use two methods for collecting horseshoe crabs: beach collection (or hand-harvesting) and trawling. Hand-harvesting usually occurs in the spring during horseshoe crab spawning season. Trawling occurs over a longer period, as trawl boats collect horseshoe crabs from their habitats on the ocean floor. A few coastal states, such as Virginia, prohibit trawling within state boundary waters. Commercial harvesters, however, often collect horseshoe crabs from waters outside Virginia state boundary waters and land them at docks within the state.

While permitting and harvest control programs by the states provide a better understanding of the commercial harvest of horseshoe crabs than has historically been available, a need for more information still exists. Much of the data currently available is qualitative and many uncertainties remain regarding reported increases in the overall crab harvest, the number of harvesters, and the geographic extent of harvesting.

Our estimates of current commercial horseshoe crab landings derive from information provided by the Atlantic States Marine Fisheries Commission (ASMFC). Over the past few years, state representatives to the ASMFC Horseshoe Technical Committee have initiated efforts to collect substantive and reliable data on the quantity of horseshoe crabs landed. As harvest control measures vary from state to state, members of the Technical Committee adapted methods for estimating horseshoe crab landings best suited to their state. As such, the final methods used by each state vary, and most states relied on data from a number of sources.[22] In addition, some states derived estimates by averaging one year of monthly landings data, while others relied on an average of the past few years. The result of this coordinated effort is an estimate of total commercial landings of horseshoe crabs for 1998. Estimates provided by each state representative were discussed and agreed upon by all members of the ASMFC Technical Committee.

By nature of the industry, accurate landings data for commercial fishing are often difficult to obtain. Differences between where fishermen actually fish and where they land their products, at-sea transfers of goods, and historic patterns of under-reporting contribute to the challenge of collecting accurate data. As such, the ASMFC estimates are characterized by the uncertainties and limitations associated with compiling this type of data. Despite these limitations, however, we believe that these estimates probably represent the most accurate and internally consistent assessment of current Atlantic Coast horseshoe crab landings to date. We base this on the fact that state representatives to the Technical Committee are most familiar with the characteristics and trends of horseshoe crabbing unique to their own state. Moreover, recent growth and fluctuations in the commercial horseshoe crab harvest combined with the lack of historical reporting complicate the use of more traditional data sources.[23]

Exhibit 3-1 presents the ASMFC estimates of horseshoe crab landings. As shown, Virginia reported the highest state horseshoe crab landings for 1998. We attribute much of this activity to a shift southward in the commercial horseshoe crab harvest, following the implementation of restrictions, limits, and partial closures in the Mid-Atlantic states. This trend

[22] Information sources typically used by state representatives include: National Marine Fisheries Service (NMFS) harvest reports, estimates derived from reported whelk and eel pot landings, interviews with fishermen, and individual state reports.

[23] NMFS maintains estimates of horseshoe crab landings in its comprehensive database of landings for fish and shellfish. The NMFS numbers, however, are based only on landings reported at docks in the presence of NMFS agents. As such, hand-harvest of horseshoe crabs is excluded from the database, as well as any commercial horseshoe crab catch not reported to NMFS agents. As a result, we determined that the data from NMFS would not provide the most accurate estimates of current horseshoe crab landings.

is further confirmed by the comparatively low landings estimates for New Jersey, Delaware, and Maryland. Whereas these Mid-Atlantic states were the center of commercial horseshoe crab harvesting only a few years ago, state controls have initiated a migration of harvesting activity. Fishermen and state contacts report that the substantial harvest reported in Massachusetts may be attributable in part to an influx of harvesters from mid-Atlantic states with restrictions on horseshoe crab harvesting.

Exhibit 3-1

ESTIMATED 1998 ATLANTIC COAST COMMERCIAL HORSESHOE CRAB LANDINGS[1]

State	Landings (No. of horseshoe crabs)
Maine	13,500
New Hampshire	200
Massachusetts	400,000
Rhode Island	100,000
Connecticut	34,583
New York	352,462
New Jersey	241,456
Delaware	479,634
Maryland	114,458
Virginia	1,015,700
North Carolina	24,036
South Carolina	--
Georgia[2]	--
Florida	5,920
TOTAL	**2,781,949**

1 As agreed upon by members of the ASMFC Horseshoe Crab Technical Committee at the October 1999 meeting. These estimates exclude landings for the biomedical industry. IEc did not perform additional verification or confirmation of these estimates.

2 Estimates for horseshoe crab landings in Georgia were not available at the time of this analysis. Information from state contacts indicates that the horseshoe crab harvest in Georgia has grown in recent years, but that it is still relatively small. Many of the horseshoe crabs landed in Georgia are believed to be caught by fishermen trawling for whelk.

Note: The ASMFC horseshoe crab landings estimates include 1998 estimates for the State of Pennsylvania. We exclude Pennsylvania from this table and our overall analysis because it plays a minor and temporary role in the horseshoe crab fishery.

NATIONAL ECONOMIC (WELFARE) CONTRIBUTION OF THE HORSESHOE CRAB — CHAPTER 4

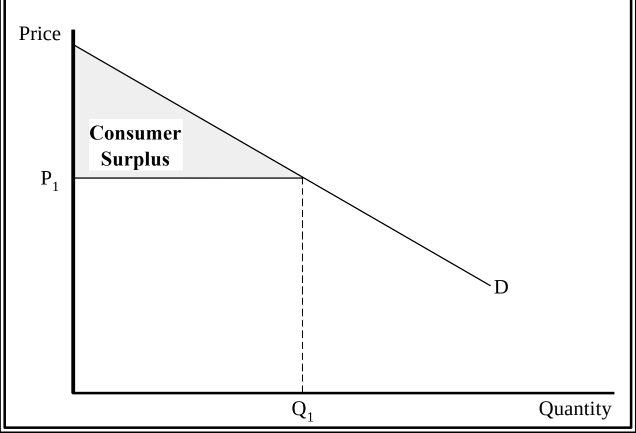
In this chapter, we evaluate the contribution of the Atlantic Coast horseshoe crab population in terms of social welfare. Horseshoe crabs create value by supporting economic activity in markets for recreational birding activities, biomedical products, and commercial eel and whelk fishing. Measuring the social welfare value created by these markets requires the application of welfare economics. In the context of this assessment, welfare economics provides an estimate of positive benefits that accrue to society at-large from competitive markets which depend on the horseshoe crab, without regard to where the distribution of impacts occurs (regional impacts are addressed separately in Chapter 5).

Below we first briefly describe the concepts and analytic approach relevant to our assessment of the annual economic welfare value of the horseshoe crab. We then describe the contribution of each horseshoe crab-dependent activity or market (wildlife viewing, biomedical, and commercial fishing).

MEASURING CONSUMER AND PRODUCER SURPLUS

A basic paradox in economics is that the monetary value of a good (or service), as measured by its price times the quantity sold, is a misleading indicator of the total economic value of that good (or service). The difference between the true value of a good and its total monetary cost is called *consumer surplus*. Consumer surplus arises when we receive more than what we pay for goods and services, due to the benefits provided by perfectly competitive markets.

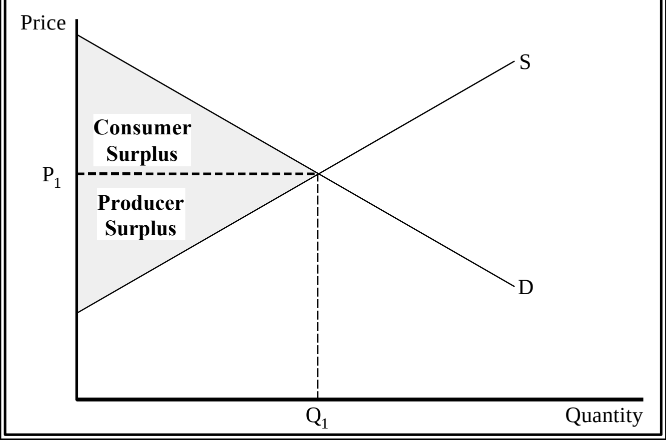
Exhibit 4-1
Consumer Surplus



This concept is best understood through an example. Assume that the fee charged to individuals for access to a wildlife viewing and recreation area is $2. Exhibit 4-1 shows the demand, (represented by the demand curve D) for use of this hypothetical recreation area. This curve shows the demand for trips to the recreation area declines as the price rises. The horizontal line indicates the current market price of access to the area (P_1). At this price, consumers will demand Q_1 trips. The shaded area represents the consumer surplus that accrues at this market price. That is, this is the positive benefit which accrues to some consumers whose willingness to pay for the recreation area exceeds the price they are actually required to pay.

An analogous concept to consumer surplus is *producer surplus*, which refers to the difference between the market price for a good and the minimum price at which a producer is willing to supply the good. This is illustrated by the lower shaded area in Exhibit 4-2, which is formed by the interaction of the supply curve (S) and market price. In this hypothetical case, the shaded area labeled "producer surplus" reflects the fact that some producers would be willing to supply this product at less than the market price and thus are able to accrue surplus. These producers therefore derive positive benefit equal in magnitude to the value of the surplus.

Exhibit 4-2
Consumer and Producer Surplus in a Competitive Market



Theoretically, estimation of the supply curve for a good or service can be done with detailed information on production costs and supply conditions. For example, a supply curve for a commercial fishing industry can be developed with information on capital costs, labor costs, other variable costs, and landings for various types of commercial fishing vessels. In actuality, firms often consider production cost information to be sensitive and/or confidential business information that may reveal their competitive position, so it can be difficult to obtain sufficient data from firms to construct an accurate supply curve for an industry.

Consumer and producer surplus together represent the total social welfare value of the relevant market. These measures provide a uniform and consistent means for quantifying benefits likely to be generated by all of the industries/user groups that utilize the horseshoe crab. For recreational birding groups that rely on the horseshoe crab, for example, consumer surplus measures the social welfare benefit derived from a birding day or trip to observe the horseshoe crab/shorebird event. Biomedical firms that use horseshoe crabs in LAL manufacturing accrue producer surplus that is equivalent to the difference between market price of LAL and firms' willingness to supply LAL. Similarly, consumer surplus accrues to pharmaceutical firms whose willingness-to-pay for LAL exceeds its market price. Finally, in the commercial eel and whelk pot fisheries, consumer and producer surplus is generated by the portion of each market which depends on horseshoe crabs for bait. By applying welfare economics, we arrive at estimates of social welfare value that are comparable across all three industries or groups.

These measures of economic benefit differ from the regional economic impacts we present in the following chapter. These include the gains or losses in industry output and employment within a specified geographic region. Recognizing that shifts within one region are often offset by counterbalancing changes elsewhere, the welfare analysis presented in this chapter is more focused on the net change in society's well-being at a national level, without regard to the regional distribution of these changes. For example, if a biomedical firm opens a new factory, regional economic analysis considers output created as a benefit to the locality where the firm resides. Welfare economics, on the other hand, only considers the output of the new firm as economic surplus when it does not displace output in another area, that is, it represents a net increase in social welfare.

In the sections that follow we describe the basis of our estimates of consumer and producer surplus for wildlife viewing/birding activities, the biomedical (LAL) industry, and the commercial fisheries that rely on the horseshoe crab, including literature and data considered in choosing values appropriate for this analysis. We then apply these values to determine aggregate welfare benefits for these markets.

WILDLIFE VIEWING/BIRDING

As we describe in Chapter 2 of this report, the major eco-tourism event related to the horseshoe crab is the visitation each spring by thousands of birders, who travel to the beaches and shores of Delaware Bay to observe the annual stop-over of large populations of migratory shorebirds. Before continuing on to breeding grounds in the Arctic, these birds descend on Cape May (and other Delaware Bay beaches) in large numbers to feed on eggs deposited by spawning horseshoe crabs. This section describes our quantitative estimate of the annual welfare value provided by the recreational birding opportunities associated with this annual phenomenon.

Note that due to the availability of existing research, this analysis focuses on estimating the value of horseshoe crab-related birding for one, highly localized and well-documented event in Cape May, New Jersey. Wildlife viewing/birding benefits associated with the horseshoe crab however, are not limited to this solitary birding event. According to wildlife biologists and other state personnel, birders are now visiting the Delaware side of the Bay during horseshoe crab migration season. Furthermore, a few biologists in the Carolinas note that the horseshoe crab migration itself is attracting interest from eco-tourism operators. As these accounts of other eco-tourist events are anecdotal in nature, we discuss them only qualitatively here. As such, we acknowledge that the quantitative estimate of value presented in this discussion is the lower-bound minimum of the actual value of current wildlife birding activities associated with the horseshoe crab.

Visitation to New Jersey's Delaware Bayshore

Eubanks et al. recent survey (1999) of recreational birders visiting New Jersey's Delaware Bayshore serves as the primary source of the wildlife viewing/birding visitation estimates and consumer surplus values used in this analysis. Where appropriate, we have modified these estimates to reflect additional information provided by New Jersey and Delaware state wildlife personnel. Furthermore, we draw only on values relevant to recreational birding activities which take place during the spring horseshoe crab/shorebird event described above.

Results of the Eubanks et al. survey suggest that visitation to New Jersey's Delaware Bayshore during the horseshoe crab/migratory shorebird event averages about 6,000 to 10,000 person-trips per year. These constitute *primary purpose* trips by birders, that is, trips that would not be taken otherwise, but for the event. State wildlife personnel in New Jersey and Delaware, however, judge this range to be rather conservative because the survey may have excluded visitors who are unaffiliated with key bird conservation groups or who visit the Bayshore on weekdays rather than weekends.[24] Given the limitations of the survey population, we estimate that 10,000 person-trips is likely to be the lower bound of visitation. Based on observations by state personnel, we estimate that 15,000 person-trips is a reasonable upper bound estimate of visitation.

Annual Social Welfare Value of Horseshoe Crab-Related Birding Opportunities

Eubanks et al. estimate birders' willingness-to-pay for experiencing the horseshoe crab/shorebird event at approximately $65 per day above and beyond direct expenditures (e.g., food, lodging) incurred during visits.[25,26] The estimated length of the average visit is about four days. These estimates are summarized in Exhibit 4-3.

Using the stated range of values for annual visits by birders during the horseshoe crab/shorebird event and the consumer surplus estimate provided, we apply these to determine the annual social welfare value of the recreational birding opportunities in New Jersey associated with the horseshoe crab population. This ranges from $2.6 million to $3.9 million per year. Exhibit 4-3 summarizes these results alongside the estimates of annual visitation and economic welfare value.

[24] Members of the New Jersey Audubon Society and/or the Cape May Bird Observatory received the survey in the mail; additional information was collected via intercept surveys administered to visitors on Cape May beaches during weekends in May 1999.

[25] This estimate of willingness-to-pay (WTP) was averaged from responses to a specific survey question asking birders how much more they would be willing to pay, above and beyond expenditures, before they would cancel their trip to witness the event. The median value for willingness-to-pay was much lower than the average WTP, at $25 per day. This reflects the influence of extreme observations on the average. Since we do not have reason to believe the extreme values are inaccurate, however, we chose to use the average and not the median value in this analysis.

[26] According to Eubanks, this willingness-to-pay estimate of $65 per day is comparable to WTP estimates for other birding events of an equally high caliber, such as the sandhill crane migration on the Platte River in Nebraska.

Exhibit 4-3 ESTIMATED ANNUAL ECONOMIC VALUE FOR HORSESHOE CRAB/SHOREBIRD EVENT IN NEW JERSEY (1999 dollars)					
Annual Trips		**Average Length of Trip**	**Welfare Estimates**	**Annual Estimate of Value**	
Lower Bound	**Upper Bound**			**Lower Bound**	**Upper Bound**
10,000	15,000	4 days	$65 per day	$2,600,000	$3,900,000

Based on discussions with New Jersey and Delaware wildlife personnel, preliminary evidence suggests that additional birders may be viewing similar horseshoe crab/shorebird events at other locations along Delaware Bay (e.g, Port Mahon, Delaware). Because the evidence that shorebird populations are relying on horseshoe crab eggs at these other sites is largely anecdotal as this point, and (more importantly) as no data exist that describe eco-tourism events being reported at other Delaware sites, no quantitative estimates for visitation are available. Thus, the above estimate does not reflect other wildlife viewing activity in Delaware Bay that is also attributable to the horseshoe crab. As noted previously, this range probably understates the actual annual social welfare value of coast-wide wildlife viewing/birding opportunities provided by the horseshoe crab/shorebird event.

BIOMEDICAL (LAL) INDUSTRY

Scientists' discovery in the 1960s that horseshoe crab blood possesses unique clotting properties enabled the development and growth of a niche biomedical industry. Using a substance derived from the horseshoe crab blood, this industry produces most of the world's supply of *limulus ameboecyte lysate* (LAL). LAL is used by pharmaceutical and biomedical firms that manufacture injectable drugs and/or intravenous medical products (e.g., catheters) to test such products for the presence of bacterial endotoxins. To be sold in the U.S. market, the U.S. Food and Drug Administration (FDA) requires that many of these end-products be screened and certified using LAL-based tests. Below we describe the 1999 market for LAL, including supply, demand, quantities sold, and market price. We then apply these values to estimate the annual economic welfare value generated by the LAL industry.

The Market for LAL

Three U.S. firms dominate global production of LAL, accounting for 80 to 90 percent of total LAL production and annual revenues. To conduct this analysis, we interviewed manufacturing and marketing experts at each of these LAL firms. Each firm's experts provided their best professional understanding of the LAL industry in 1999, including total revenues, number of horseshoe crabs bled, product and raw material prices, and production data.[27]

[27] We used 1999 information for this analysis after determining that it was not an unusual year for the industry. In some instances, industry contacts provided us with firm-specific sales and production data. To assuage concerns over the publication of sensitive business information, we requested that they extrapolate data from their own firm to arrive at an industry estimate. In this report we present only industry estimates, not firm-level data.

According to LAL industry experts, the LAL industry bled approximately 200,000 to 250,000 horseshoe crabs in 1999.[28] Based on descriptions of the product mix sold by the LAL industry, we establish that the relevant unit of measure in the LAL market is the *number of test equivalents*; that is, the number of pharmaceutical product tests supported by the quantity of LAL sold. By using this unit of measure, we normalize for the following differences across LAL-based products and LAL firms:

- LAL-based products are typically bundled in kits along with related products (e.g, reagent water) and services (e.g., technical guidance); and
- LAL-based test kits contain varying quantities, concentrations, and sensitivities of LAL.

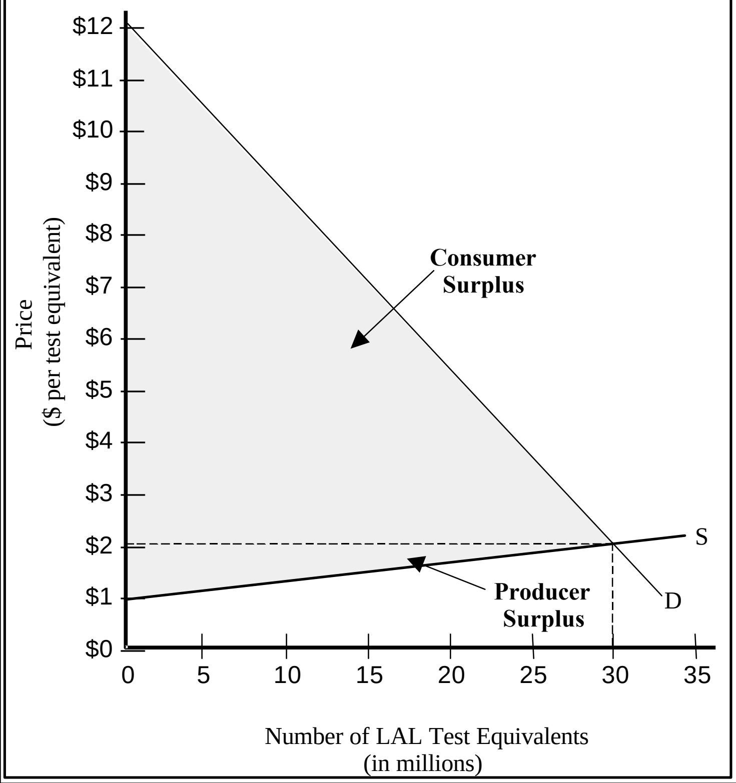
Industry experts estimate the total number of LAL-based test equivalents sold in 1999 at 30 million.[29] Global sales revenues in the LAL industry in 1999 were approximately $60 million. Assuming total sales revenues equal market price times units sold, we estimate that the market price equals $2 per LAL-based test equivalent. Exhibit 4-4 depicts the LAL market, with this estimate of market price ($2) shown.

[28] According to FDA requirements, firms in the LAL industry are required to return crabs to their aquatic environment after partially bleeding them. The bleeding process results in an estimated 10 to 15 percent mortality rate (Atlantic States Marine Fisheries Commission, 1999).

[29] Experts within each firm calculated the number of test equivalents supported by the product mix sold by their own firm in 1999, and then extrapolated to a total for the industry using knowledge of relative market share. These industry totals translate roughly to an estimate that each horseshoe crab bleeding supports 120 to 150 LAL test equivalents.

To develop estimates of consumer and producer surplus for the LAL market, we first must consider the sensitivity of demand and supply to the market price of LAL.[30] The responsiveness of demand (or supply) of LAL to a given change in market price is known as the *elasticity of demand (or supply).* It is elasticity, or the market's responsiveness to price, that generally defines the shape of the demand and supply curves. From Exhibit 4-4, it is easy to observe that the shape of these curves influences consumer and producer surplus.

Exhibit 4-4
The LAL Market



Given a lack of historical or current market data that can be used to infer demand and supply elasticities for the LAL market, we developed a sense of demand elasticity based on the professional opinion of LAL manufacturers, FDA experts, and pharmaceutical companies that form the market for LAL. We find that demand for LAL is *highly inelastic* in the short-run, which can be attributed to the following key factors:

- **FDA requirements.** FDA requires that pharmaceutical and biomedical manufacturers use LAL to test end-products for the presence of endotoxins before releasing them to the U.S. market.[31] Furthermore, these firms have established manufacturing processes using LAL-based testing protocols which would be costly to change. These factors combined virtually guarantee that short-run demand for LAL would be relatively firm (i.e., inelastic) in the event of a price increase.

[30] Note that elasticity is a measure of response to changes in *market* price, rather than unilateral changes in price by one or more individual firms. If one firm in a competitive market lowers price (all else being equal), demand for their product will increase. This firm will obtain a greater share of the overall market at the expense of firms that maintain the higher price, all else being equal. Aggregate market demand does not necessarily change unless the firm that changes price possesses market power substantial enough to "move the market."

[31] See 21 C.F.R. § 660.

- **Absence of viable substitutes.** In the U.S., end-product testing with LAL has replaced its predecessor, the rabbit fever test, as the industry standard. Alternative tests based on non-LAL derivatives (e.g., human white blood cells) are currently under research and development, but are likely to be five to 10 years from commercial viability.[32]

- **Steady market growth.** Growth in the global market for LAL has held steady at about eight to 10 percent per year in recent years, fueled mostly by growth in demand from overseas.[33] This rate of growth seems secure, as FDA requirements create incentives for biomedical sectors in developing countries to switch to LAL-based testing (from rabbit-fever testing), so that they can then export to the lucrative U.S. market for pharmaceuticals.

In the next section, we apply the above insights to arrive at an estimate of social welfare value for the industry.

Annual Social Welfare Value of the Biomedical (LAL) Industry

To estimate the annual social welfare value contributed by the LAL industry, we first apply expert opinion to arrive at a demand elasticity for LAL. Based on experts' assertions that demand for LAL would likely suffer only a marginal decline (i.e., five percent or less) in the event of a 25 percent increase in price, we calculate demand elasticity as equal to approximately -0.2.[34] Consistent with economic theory, we assume that demand becomes more elastic with each additional price increase.[35] Increasing elasticity implies the slope of the demand curve remains fairly constant, so we calculate the price when demand equals zero (i.e., a 100 percent reduction in demand) as $12 per test equivalent.[36] We then calculate the value for consumer

[32] Based on personal communication with Dr. Alberto Guittierez, Center for Biologics Evaluation and Research, U.S. FDA (December 1999).

[33] In Europe, the governing body for the pharmaceuticals industry (the European Pharmacopoeia) has similar requirements for LAL-based testing of end-products.

[34] We compute price elasticity of demand by calculating the *point elasticity of demand* as follows: [(Change in Quantity demanded/ Quantity demanded)/(Change in Price/Price)].

[35] Microeconomic theory states that each successive increase in price will further reduce a consumer's *marginal utility*, or in this case the satisfaction derived from each additional unit of LAL purchased.

[36] In most empirical studies, price elasticity of demand does vary from one point to another on a given demand curve. For a detailed description of this analysis, see Appendix 4-A.

surplus (in Exhibit 4-4, the area below demand and above market price) to be approximately $150 million.[37]

Producer surplus in the LAL market is equivalent to the difference between market price and the price at which producers are willing to supply LAL (in Exhibit 4-4, the area above supply and below market price). As we lack data that describe the cost structure of firms in the LAL industry, we assume that supply conditions are comparable to those in most industries. That is, LAL supply will increase as price increases (i.e., the supply curve slopes upward to the right). This reflects the fact that as price increases, LAL producers have greater incentives to produce and offer LAL for sale. Given the absence of available data describing the actual cost structure of the LAL industry, we do not provide a quantified estimate of producer surplus in this analysis. However, the supply line and corresponding producer surplus estimate shown in Exhibit 4-4 probably represent a reasonable approximation of supply conditions in the LAL industry. Obviously, if costs of LAL production are lower (or higher) than depicted here, then a larger (or smaller) surplus will accrue to producers. Regardless, what is clear is that consumer surplus is the more substantial component of annual social welfare value in the LAL industry.

According to our analysis of the 1999 market, in the short-run (less than five years) the LAL industry will generate substantial social welfare value. The finding of significant social welfare value is common to industries and products such as LAL that incorporate substantial intellectual capital. Moreover, the LAL industry derives market power from the presence of FDA regulatory requirements, which create inelastic demand and constitute a barrier to entry.[38] In conclusion, significant price increases will eventually spur greater investment in viable substitutes in the long-run (five to ten years), but in the interim the LAL industry will continue to generate annual social welfare value of over $150 million.

COMMERCIAL FISHING

The horseshoe crab serves as an important bait source for two Atlantic Coast commercial fisheries, the whelk pot fishery and the American eel pot fishery. Estimates of the number of horseshoe crabs used in 1998 as bait in commercial fishing total 2.8 million, an estimated 85 percent of which serve as bait in the whelk pot fishery.[39] While the two fisheries use the

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[37] We calculate the welfare value, or the area in the consumer surplus "triangle," as follows: 1/2(base)*(height), or 1/2(30 million)($12-$2) = $150 million.

[38] Although LAL is not patented, FDA requires that all manufacturers producing LAL for end-product testing be licensed by the Center for Biologics Evaluation and Research (21 CFR ' 660). Acquiring a license for LAL manufacturing requires significant administrative effort, as well as establishment of a specific manufacturing protocol. Given the significant up-front investment and knowledge required to obtain an FDA license to manufacture LAL for end-product testing, we feel these constitute a barrier to entry by new producers.

[39] We assign 85 percent of the 1998 ASMFC Atlantic Coast horseshoe crab landings (excluding landings for biomedical use) to the whelk pot fishery based on an 85 percent/15 percent ratio between whelk demand and eel demand, provided to us by members of the ASMFC Horseshoe Crab Advisory Board and Technical Committee.

horseshoe crab for bait in similar ways, the characteristics of the markets for whelk and eel and the economic welfare generated by each differ substantially. In the sections below, we discuss the characteristics of the supply and demand for each fishery.

To conduct social welfare analyses for the whelk and eel pot fisheries, we developed methodologies based on available information. As such, both methodologies include estimations and key uncertainties at several steps in the analyses. For example, both analyses rely on the use of an average seasonal yield of whelk or eel (in pounds) per fishermen. In addition, we apply estimates of the average quantity of horseshoe crab bait required per whelk or eel potter seasonally. To the extent that fishermen typically yield more or less in a season, or require more or less horseshoe crab bait, our analyses may overestimate or underestimate the total size of the fisheries. When possible, we use other methodologies to cross-check the results of our analysis.

Whelk Pot Fishery

The whelk pot fishery in the United States runs from Massachusetts south to the Carolinas. At present, the states reporting the most significant landings of potted whelk include Massachusetts, New York, and Virginia. In addition, New Jersey, Delaware, and Maryland report sizeable landings of potted whelk. North of Massachusetts and south of the Carolinas, state fisheries management personnel report that whelk potting does not occur, largely because water temperatures are too cold or too warm. Whelk potting is a seasonal fishery which generally runs from April through December. In 1998, the whelk pot fishery used an estimated 2.4 million horseshoe crabs as bait.

The Market for Whelk

We base our analysis of the annual social welfare value generated by the whelk pot fishery on information gathered through personal communication with whelk fishermen and processors, state fisheries management personnel, and industry representatives. At present, demand for whelk meat exists in both domestic and international markets. Domestically, a significant portion of the demand comes from ethnic markets concentrated in the Northeast and Mid-Atlantic. Internationally, demand for whelk meat is concentrated in Asia, with Hong Kong being the largest importer of U.S. exports of whelk in recent years. It is important to note that demand for whelk has grown significantly in the past 10 to 15 years. While some states, such as New York, report commercial whelk pot activity dating back 20 to 25 years, most have no record of a commercial whelk pot fishery prior to the late 1980s. Most states, however, report significant growth in commercial whelk potting in recent years, largely attributable to management restrictions on other fisheries and/or declining populations of other commercial species.

As the first step in our analysis, we estimate the size of the whelk pot fishery. To accomplish this, we multiply of the number of whelk boats per state by the average number of pounds of whelk caught seasonally per boat to arrive at estimated total whelk pot landings by state for the Atlantic coast.[40] We derive an estimated number of pounds caught seasonally per boat by averaging daily, weekly, and seasonal yields provided to us by whelk pot fishermen in different states. Based on this method, we calculate that between 11.4 million and 15.4 million pounds of whelk in-shell are currently landed each year along the Atlantic Coast.

Once landed, whelk in-shell are sold to processors who prepare the whelk meat for sale to wholesale markets. Whelk processors remove the shell and extract the meat inside, which may be sold as a cooked or fresh (raw) product. With the cooked product, the whelk meat may be steamed and packaged frozen or steamed and canned. According to whelk processors and industry representatives, whelk in-shell yields (on average) 23 percent of its weight in whelk meat. Using this average yield, we estimate that, at present, between 2.6 million and 3.5 million pounds of whelk meat are sold annually to domestic wholesale and foreign export markets. Taking the average of this range, we arrive at an estimated 3.1 million pounds of whelk meat per year at the wholesale level.[41] Based on communication with whelk processors and wholesalers, the current average retail price per pound for whelk meat is $5.50.[42]

To derive an estimate of the social welfare value generated by the whelk pot fishery, we first examine the supply and demand in the retail market for whelk. The market's responsiveness to changes in price, or elasticity, generally defines the shape of the demand and supply curves.[43] In this case, the price elasticity of demand (or supply) for whelk refers to the responsiveness of

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[40] Our estimates of the number of whelk boats per state are based on information provided to us by fishermen, whelk processors, and state fisheries management personnel. In general, the number of licensed whelk potters exceeds the number of boats estimated because a number of licensees are not actively fishing for whelk. In addition, we limit our analysis to those boats for whom whelk potting constitutes a significant portion of annual income. As some fishermen achieve this through part-time potting and others through full-time potting, we average estimates of the number of full-time and part-time fishermen for our analysis. We checked our estimates of the number of whelk boats per state against the number of whelk boats per state derived by working backwards from ASMFC's 1998 horseshoe crab landings data. By dividing each state's horseshoe landings by an average bait use per whelk fishermen (Munson), we arrived at an average number of whelk boats per state that fell within close range to our estimates.

[41] Because some percentage of total whelk landed is likely to be lost due to spoilage during transportation and storage, we may slightly overestimate the total quantity of whelk meat sold annually at the wholesale level.

[42] This market price represents the average of market price estimates for several varieties of whelk sold at the retail level, including fresh, frozen, and canned meat.

[43] In this analysis of social welfare, we limit our consideration of the supply and demand for whelk to the point of retail purchase. Based on consideration of the market fundamentals at each point along the "value chain" for whelk, we determine that surplus generated in the retail market fully captures surplus generated at earlier points in the value chain.

end-market consumers (or suppliers) to changes in the retail market price of whelk. As very little data exist that describe the retail market, our estimation of the characteristics of the market demand and supply relies on personal communication with industry and market representatives.

Based on information provided by individuals working in the industry, we determine that supply and demand for whelk are both relatively sensitive to market price. In particular, we estimate that consumer demand for whelk is extremely price sensitive (i.e., highly elastic).[44] The following characteristics of the whelk market contribute to the sensitivity of demand to price:

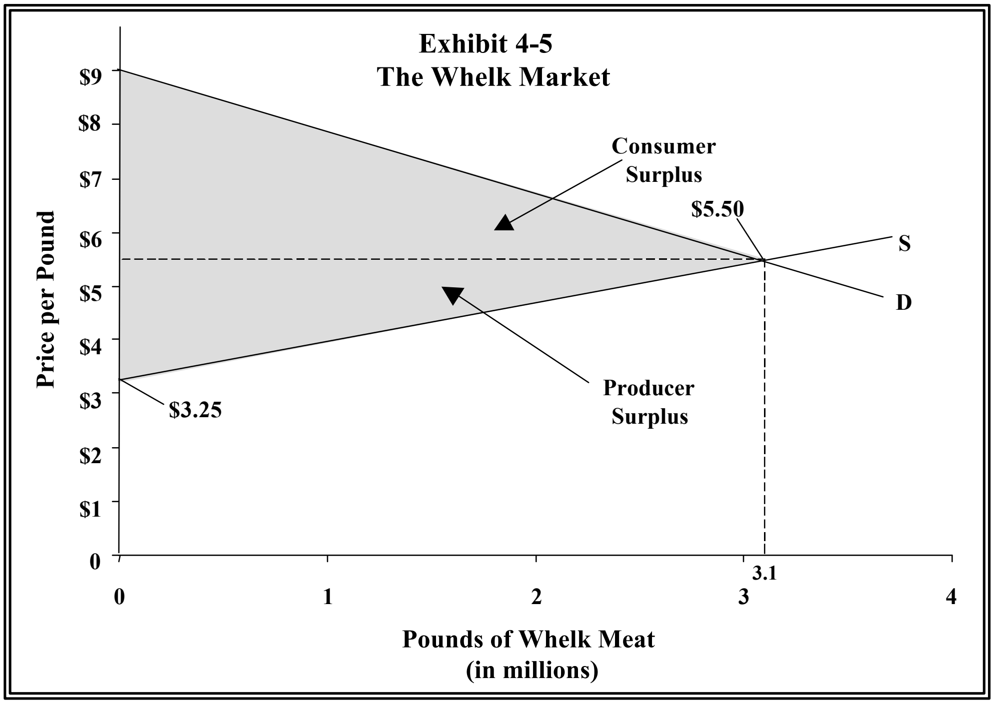
- **Availability of substitutes:** As a seafood product, whelk meat is generally sliced for use in salads, sauces, and pastas. According to industry representatives, other shellfish commonly substituted for whelk meat include squid, scallops, and clams. Given the range and availability of comparable substitutes, consumers can switch to other products in the event of an increase in the price of whelk.

- **Absence of a specialty market:** For certain goods, niche markets with inelastic demand may develop, for example, if cultural or religious traditions dictate the use of a good. As there is no evidence suggesting that whelk meat occupies an important niche in a particular market, we conclude that there are no significant specialty markets for whelk. While much of the current demand is attributable to ethnic markets and evidence exists that whelk meat is popular during the holiday season, these markets are general enough that demand for whelk can be variable.

As a result of these characteristics, we determine that the demand for whelk is *highly elastic* in the short-run. Exhibit 4-5 below displays our characterization of the market for whelk meat.

The average price in the retail market for whelk meat is represented by the intersection of the supply and demand curves. As displayed, we estimate that at the current market price of $5.50 per pound, 3.1 million pounds of whelk meat are sold to the U.S. retail market as well as the export market. While we do not have the dockside price for whelk exported by the U.S., we assume any difference between the dockside price and domestic market price is due to transport costs. Exhibit 4-5 also displays a relatively flat (horizontal) demand curve for whelk, indicating *elasticity* in the demand for the product. As shown, increases in the price of whelk meat result in significant reductions in the quantity demanded.

[44] We received significant input from wholesalers indicating that demand for whelk is largely a function of price, rather than other product attributes. According to these contacts, consumers buy whelk because it is affordable, and demand for the product would not withstand a sharp increase in price.



Annual Social Welfare Value of the Whelk Pot Fishery

In the first step towards estimating the total annual social welfare value generated by the whelk pot fishery, we derive an estimate of the price elasticity of demand for whelk. To accomplish this, we rely on industry characterizations provided to us by whelk fishermen, processors, wholesalers, and retailers along the Atlantic Coast. According to input from these contacts, a 25 percent increase in the retail price for whelk would result in a reduction in quantity demanded of approximately 40 percent. Based on these projections, we estimate the demand elasticity for whelk at -1.6.[45] Using this calculation of demand elasticity, we estimate that demand for whelk meat would be reduced to zero given an average price per pound of $9.00. Exhibit 4-5 graphically displays a 100 percent reduction in demand for whelk given a market price of approximately $9.00. To estimate the annual social welfare value generated by the whelk pot fishery, we estimate consumer surplus by calculating the size of the area below the demand curve and above market price. For this analysis, we estimate the consumer surplus generated by the whelk pot fishery to be $5.4 million.[46]

To consider the producer surplus generated by the whelk pot fishery, we examine the difference between market price and the price at which wholesalers or retailers are willing to supply whelk meat. To determine the shape of the supply curve for whelk meat, we assume that

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[45] As reported earlier in Chapter 4, price elasticity of demand is calculated using: [Change in Quantity demanded/Quantity demanded)/(Change in Price/Price)].

[46] We calculate the area in the consumer surplus "triangle" as follows: 1/2(base)*(height), or 1/2(3.1 million)*($9.00-$5.50) = $5.4 million.

whelk is similar to most competitive industries in that supply generally increases as price increases. Moreover, we assume that most retailers will not sell whelk meat significantly below the average wholesale market price, estimated to range from $3.80 to $4.50.[47] As a result, we assume a supply curve that slopes upward to the right from a y-intercept at approximately $3.25, as shown in Exhibit 4-5. Note that our estimation of the supply curve indicates a mild slope upward; this reflects the fact that, for many fishermen, there is relative ease of entry into and exit from whelk potting.[48] As many whelk fishermen alternate whelk potting with other pot fishing and line fishing, we assume that there are few barriers to entry when demand for whelk is high. In addition, the recent growth and development of the whelk pot fishery further suggests that supply for whelk is elastic, and has responded quickly to restrictions and population declines in other fisheries over the last 10 to 15 years.

Alternatively, the rapid rise of the industry, as well as the fact that whelk potting does not require significant dedicated capital, suggest that fishermen could and would switch out of whelk potting if it became unprofitable as quickly as they moved into whelk potting after demand initially developed. Both of these trends indicate a degree of flexibility in the supply of whelk meat. Without actual market data it is difficult to estimate producers surplus, but using the assumptions shown here, a reasonable estimate of producer surplus is $3.5 million.[49]

In summary, our analysis suggests that the social welfare generated by the current whelk pot fishery totals approximately $8.9 million. Of this, we estimate that approximately $5.4 million may be attributed to consumer surplus, and approximately $3.5 million may be attributed to producer surplus. These estimates are generally consistent with industry information indicating that the whelk fishery behaves like other natural resource commodities, and that supply and demand for whelk is very elastic.

The Eel Pot Fishery

Commercial potting for American eel occurs in all Atlantic coastal states from Maine to Florida, but the size of the pot fishery varies significantly from state to state. For example, fishermen and state contacts indicate that sizeable eel pot fisheries exist in Virginia, Maryland and Florida, while Georgia and North Carolina report small numbers of fishermen potting for eel.

[47] We assume that because supply is elastic and the market price is approximately $5.50, it is reasonable that supply of whelk would decline to zero at some price between $2.00 and $4.00. We imagine that there are likely to be occasions in the short run when suppliers sell whelk meat to the retail market at or below the average wholesale price. In the long run, however, suppliers who cannot cover both fixed and variable costs will eventually leave the market.

[48] The relative barriers to entry into and exit from this market are obviously influenced by the availability of permits for whelk potting and for other fisheries. As permit rules and regulations vary significantly between states, we do not address them in this analysis.

[49] We approximate the area in the producers surplus "triangle" as follows: 1/2 (3.1 million) * ($5.50 - $3.25) = $3.49 million.

Similar to the whelk pot fishery, eel potting is very sensitive to water temperature. Fishermen report that eel can be caught by pot in temperatures above 52 F degrees and below 80 F degrees. These temperature restrictions generally allow for a potting season that runs from spring through fall/early winter, although regional variations exist and fishermen in the southern states report a brief hiatus in eel pot activity during the warmest summer months.

While horseshoe crab is a bait commonly used by eel pot fishermen, it is not the only available bait source for eel potting, and many eel fishermen presently report using other products as their primary bait for eel potting. To some extent, the size and availability of horseshoe crabs largely affects this decision. For example, eel potters in Maine report that local horseshoe crabs are too small for eel potting purposes; as a result, herring and crushed blue mussels are the preferred products. Even in regions along the coast where large horseshoe crabs exist, however, many states report other bait sources are used or even preferred by fishermen. For example, state fisheries management personnel in Virginia report that eel potters regularly use blue crab as eel bait, and North Carolina state contacts report that eel potters commonly rely on shrimp heads.

The Market for Eel

As mentioned briefly in Chapter 2, the principal markets for eel caught by pot include a domestic and international consumption market, as well as a domestic market for live eels as bait for striped bass fishing. Foreign demand for potted eel is concentrated in Europe and Asia, where the product is consumed raw, cooked, or smoked. Domestic demand for eel as a food product is largely concentrated in ethnic and seasonal markets, although in recent years its appeal has expanded outside specialty markets. Domestic demand for eel as bait exists in both the recreational and commercial striped bass fisheries, as live eels are considered among the best baits for catching striped bass. The growth of recreational striped bass fishing in recent years has greatly contributed to a significant increase in demand for live eels.

To evaluate the social welfare value generated by the eel pot fishery, we first estimate the size and market characteristics of the industry. In the case of the eel pot fishery, our analysis is greatly limited by the lack of substantive and reliable information on industry trends and patterns.[50] We attribute much of this lack of data to the challenges inherent in tracking a fishery where multiple domestic and international markets exist, and where demand for eel is highly variable according to the life stage and size of the species, intended use, region, and season. Our analysis is complicated further by the fact that we only analyze the portion of the eel pot fishery attributable to potting with horseshoe crab as bait, as many eel potters rely on other baits. To develop a characterization of the portion of the eel pot fishery of concern to our analysis, we rely

[50] Similar to the complications involved in using NMFS horseshoe crab data, the NMFS data for eel only includes those landings reported at dock and recorded by a NMFS agent. As such, many eel landings at various life-stages are not included in NFMS numbers.

on information provided to us by fishermen, dealers, and state fisheries management contacts working in the fishery. In addition, we contacted several members of the ASMFC American Eel Technical Committee.[51]

Given these complications with obtaining accurate data on the portion of the industry of concern to our analysis, we derive estimates of eel landings attributable to horseshoe crab use by working backwards from an estimate of the number of horseshoe crabs used as bait for eel potting. To accomplish this, we rely on the ASMFC's approved estimates of horseshoe crab landings for the Atlantic Coast. Of the total 2.8 million horseshoe crabs landed along the Atlantic Coast in 1998, we attribute 15 percent of these landings to eel potting, which yields an estimate of 417,000 horseshoe crabs used coast-wide for bait in eel pots.[52] We divide this total number of horseshoe crabs by an average bait use per eeler, in this case 4,700 horseshoe crabs per season.[53] This calculation yielded us an estimate of the number of eel potters per state along the Atlantic Coast.[54] We sum the count of eel potters in each state to arrive at a total estimate of 89 eel potters coast-wide relying on horseshoe crab as a significant bait. We adjust our estimate of the total number of eel potters from 89 to 99 based on the recommendation by Florida State fisheries management personnel to increase our estimate of the number of eel potters in Florida by 10. Using this estimate of the number of eel potters, we derive a range for total estimated landings by multiplying the number of eel potters by high and low estimates of seasonal yield (in pounds) per eel potter. We obtain estimates of seasonal yield based on

[51] In addition to a general lack of data on the eel fishery, communication with fishermen, dealers, state fisheries management personnel, and industry representatives yielded conflicting information about the size and principal markets of the eel pot fishery. As a result, we use the average of estimates provided to us by various contacts and apply conservative estimates in all calculations.

[52] We assign 85 percent of the 1998 ASMFC Atlantic coast horseshoe crab landings (excluding landings for biomedical use) to the whelk pot fishery based on an 85 percent/15 percent ratio between whelk demand and eel demand provided to us by members of the ASMFC Horseshoe Crab Advisory Board and Technical Committee.

[53] The average bait use per eeler is taken from an analysis of bait requirements for the eel and whelk fisheries in New Jersey and Delaware, based on a questionnaire administered to fishermen (Munson, 1998). In addition, we queried individual eel potters in the Mid-Atlantic and South for estimates of their horseshoe crab bait use per season. We found that estimates provided by individual eel potters fell in the range of Munson's average, so we applied this estimate in our analysis.

[54] As with our analysis of the whelk fishery, our estimates of the number of eelers refers to an estimate of the number of fishermen who spend a substantial portion of time eel potting, or for whom a significant portion of their income is derived from eel potting. We exclude from this analysis eel fishermen who pot occasionally for eel and for whom other fisheries provide most of their income.

personal communication with eel pot fishermen in the Mid-Atlantic and South. Based on this communication, we apply estimates of 15,000 to 20,000 pounds per eeler per season to arrive at a range of 1.5 million to 2.0 million pounds of eel landed annually in recent years along the Atlantic Coast by eel potters using horseshoe crabs as bait.[55]

Once landed, eel potters generally sell their live eel landings to dealers who distribute and sell the product to retail providers, bait shops, or export markets. On occasion, some eel potters sell their eel landings directly to bait shops. Both the market for eel consumption and the bait markets maintain the eels for live sale. According to eel fishermen and members of the ASMFC's Eel Technical Committee, approximately 60 percent of the total eel potted along the Atlantic Coast goes to consumption markets, either foreign or domestic. Using this, we estimate that the total quantity of potted eel going to consumption markets ranges from 0.9 million to 1.2 million pounds. Based on communication with industry representatives, we attribute the remaining 40 percent of potted eel landings to the striped bass bait market. As such, we estimate that the total quantity of potted eels sold for bait purposes along the Atlantic Coast ranges from 0.6 million to 0.8 million pounds, or an average of 0.7 million pounds.[56]

For our analysis of the social welfare value generated by the eel pot fishery, we consider the elasticity of supply and demand in the consumption and bait markets for eel. As with the whelk fishery, we focus on supply and demand at the point of retail purchase.[57] Based on communication with industry representatives and dealers, we determined that the consumption and bait markets have different market characteristics. As a result, we consider them separately in this analysis.

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[55] We base our estimates of total potted eel landings on the most recent ASMFC approved horseshoe crab landings, which are based on activity from 1996 to 1998. As such, our analysis implicitly assumes that the eel potting activity over the past two to three years is representative of eel potting activity over time. To the extent that the past two to three years does not accurately represent the eel pot fishery, we may overestimate or underestimate total eel potting activity.

[56] As we only examine that portion of the potted eel market attributable to horseshoe crab bait, we did not locate any information sources providing comparable data against which to check our estimates. NMFS data and U.S. export statistics do not isolate potted eel from eels caught by other methods, and no sources distinguish landings according to bait source. As a result, we could not perform verification of our estimates of total eel landings.

[57] As in our analysis of the whelk fishery, we assume that surplus generated in the retail market fully captures surplus generated at earlier points.

Our analysis of the consumption market for eel is greatly inhibited by limited available information and complications associated with available information.[58] Personal communication and data gathering yielded estimates of the average market price for potted eels sold to consumption markets. We did not, however, obtain adequate information on the suppliers, consumer preferences, and price sensitivity of potted eel to accurately represent the supply and demand curves. Based on communication with eel fishermen, dealers, and state contacts, we estimate that the average retail price for potted eels sold for human consumption ranges from $4.50 to $6.50 per pound. As mentioned above, we estimate that approximately 0.9 million to 1.2 million pounds of potted eel are sold at this price. A lack of information on available substitutes, industry growth, specialty markets, and pricing trends precludes any further characterization of the sensitivity of the market to price.

Our research on the retail market for potted eel used as bait in the striped bass fishery yielded better information, although we lack sufficient data to fully characterize the industry. Based on personal communication with dealers and bait shops, we derive the average retail price of live eels sold as bait for striped bass, as well as basic characteristics of the market.[59] One key difference in pricing between the bait and consumption markets derives from the fact that bait eels are sold by the eel and not by weight. Live eels sold for bait purposes are sold by the eel to facilitate commercial transactions with recreational fishermen who prefer to purchase small quantities of eel. Bait shop owners indicated that, on average, six bait eels equal one pound and the average recreational fisherman purchases between five and 10 eels.[60] Thus, we assume that, on average, recreational fishermen purchase approximately one pound of eels. According to industry representatives, the retail price for live eels sold as bait ranges from $1.10 to $1.50 per eel. Taking an average of this range, we derive an estimated retail price of $1.30 per eel. Using an average of 7.5 eels per eel fishermen with the average retail price of $1.30 per eel, we estimate that the average price per pound of live eels for bait use equals $9.75. Given this average price per pound, we estimate that between 0.6 million and 0.8 million eels are sold annually for recreational bait purposes at the average price of $9.75 per pound.

We estimate the sensitivity of the bait eel market to price based on personal communication with bait shop owners and eel dealers. In general, bait shop owners indicated that, of the recreational fishermen currently fishing with live eels, a majority would continue to purchase live eels given a sizeable increase in price. Principal reasons for this include:

[58] Complications associated with available information on the eel fishery derive from the fact that most sources report information on eel in aggregate, including eel of all ages and sizes. As a result, we could not distinguish eels caught by pot from eels caught by other methods (i.e, nets or weirs).

[59] We derive our characterizations of the striped bass fishery based on characteristics of the recreational striped bass fishery. While we acknowledge the presence of a commercial striped bass fishery, we did not obtain adequate information to analyze the commercial market separately from the recreational market.

[60] Eels suitable for use as bait in the striped bass fishery range from 10 to 15 inches in length.

- **Preferred bait source:** Eel fishermen, dealers, and bait shop owners indicate that yield when striped bass fishing with live eels far exceeds the yield with other available baits. Fishing with live eels requires knowledge such that some recreational fishermen do not use them, but demand for live eels among skilled fishermen is very high. Thus, while other bait sources exist, industry representatives indicate that fishermen familiar with live eels would continue to demand live eels given an increase in price.

- **Comparatively small cost:** According to bait shop owners, the cost of bait is a small percentage of the total cost incurred by many recreational striped bass fishermen for a day of fishing. As the activity requires expensive fishing and boating equipment, or the rental of equipment and a guide, the expense attributable to live bait is relatively minimal. Moreover, many fishermen plan a day of striped bass fishing significantly in advance of the date of activity. This preparedness in advance to spend a large amount of money likely increases fishermen's willingness to pay to continue using the same bait source.

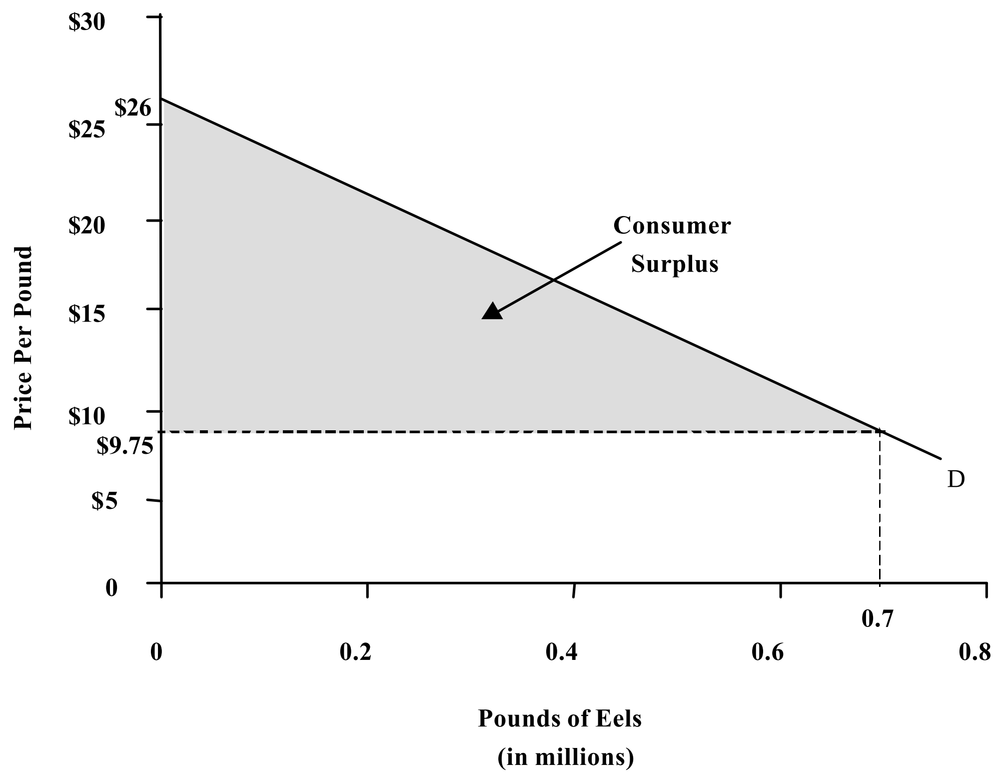
Annual Social Welfare Value of the Eel Pot Fishery

Given these factors, we determine that the demand for live eels is somewhat *inelastic*, or able to withstand increases in price. Several bait shop owners projected that a significant drop in demand would not occur until the cost of live eels rose to roughly $20.00 per pound. Based on these projections and communication with other industry representatives, we estimate that a 50 percent increase in price would result in roughly a 30 percent drop in demand. As a result, we calculate an elasticity of demand for the live eel bait market equal to approximately -0.6. Exhibit 4-6 below depicts our understanding of the market for live eels in the recreational striped bass fishery.

As shown in Exhibit 4-6, we estimate that the demand for live eels as bait for recreational striped bass fishing will decrease by 100 percent given a price increase to approximately $26.00 per pound. To estimate the consumer surplus generated by the eel pot fishery, we calculate the area below the demand curve and above market price.[61] For this analysis, we estimate the total consumer surplus value to be $5.7 million.

[61] We calculate the area in the consumer surplus "triangle" as follows: {1/2 (base)*(height)}, or {1/2(0.7)*($26.00-$9.75)} = $5.7 million.

Exhibit 4-6
The Market for Live Eels as Bait
in the Recreational Striped Bass Fishery



Information describing the nature of the supply-side of the eel industry, in either qualitative or quantitative form, is not sufficient to reasonable approximate producer surplus generated by the retail market for live eels in striped bass fishing. Therefore, we determine that $5.7 million is a lower-bound estimate for the total social welfare surplus generated by the Atlantic Coast eel pot fishery.

SUMMARY AND CONCLUSIONS

The Atlantic Coast horseshoe crab population generates social benefits by supporting economic activity in three distinct industries: recreational birding, the biomedical (LAL) industry, and commercial whelk and eel pot fisheries. Exhibit 4-7 summarizes results based on our analysis of market fundamentals (price, quantity sold, price elasticities), as described by industry and other experts.

Exhibit 4-7

SUMMARY OF RESULTS

Industry/User Group	Annual Economic Surplus	Key Conclusions
WildlifeViewing/ Birding	$2.9 million to $3.6+ million	• Birders find the event to be unique and high in quality, which is also reflected by their relatively high willingness-to-pay ($65 per day).
Biomedical (LAL) Industry	$150+ million	• Significant consumer surplus (CS) results from *highly inelastic* demand for LAL, which is due to FDA requirements, a lack of commercially viable substitutes, and growth from emerging overseas markets.
Whelk Pot Fishery	$8.9 million	• The whelk pot fishery uses the largest portion (almost 90 percent) of horseshoe crabs destined for fisheries bait markets. • Whelk has emerged as a commercial product only in the last ten years. • Whelk occupies the low-end of the shellfish market and has many substitutes, so demand is price-sensitive (i.e., elastic). • Market supply of whelk is believed to be similarly elastic.
Eel Pot Fishery	Striped bass bait market: $5.7+ million; Consumption market: not quantified, but less than $5.7 million.	• As eel pot fishers use other baits in addition to horseshoe crabs (e.g., surf clams), this fishery accounts for under 20 percent of total horseshoe crabs sold as bait. • Recreational striped bass fishery generates much of the derived demand for horseshoe crabs, as eel is a preferred bait in this fishery.

There are a few noteworthy limitations associated with these results. In this analysis of horseshoe crab-dependent birding activities, we address only the Delaware Bay event where birders concentrate during horseshoe crab spawning season. As such, these estimates do not reflect all eco-tourism events that may be reliant upon the horseshoe crab, and we may thereby underestimate total social welfare value from wildlife viewing/birding as a result. To develop our estimates of surplus generated by the biomedical (LAL) and commercial fishing industries, we relied almost exclusively on the best judgement of industry experts. As such, our results are sensitive to the validity of information provided by these experts. Results of our independent analysis of the industry value chains, however, do confirm the reasonableness of our welfare estimates.

REGIONAL ECONOMIC IMPACTS OF THE HORSESHOE CRAB **CHAPTER 5**

INTRODUCTION

In this chapter, we focus on the contributions of horseshoe crab-dependent industries to the regional economies in which these activities take place. To conduct this analysis, we employ an analytical approach known as regional economic analysis. Regional economic analysis provides a means of estimating the impact of a policy or other change on a local economy by quantifying changes in output and employment. Due to the interconnected nature of industries in a geographic area, changes in one industry or economic sector tend to have proportionately larger effects on regional output and employment. This concept is commonly referred to as the "multiplier" effect. To characterize these impacts, we use an analytic approach known as *input/output modeling*.

To conduct regional economic analysis of the Atlantic Coast horseshoe crab population using an input-output model, we measure the contribution of each industry and user group by considering what changes would take place if the horseshoe crab resource became unavailable.[62] Under this modeling scenario, we anticipate the following categories of changes:

- Local spending on food, lodging, and equipment by recreational birders visiting the Delaware Bay during horseshoe crab spawning season.
- Output and employment by LAL producers, which use horseshoe crab blood as the primary input to their product line.
- Local spending associated with the American eel and conch pot fisheries that rely on horseshoe crabs for bait.

[62] While this hypothetical situation is obviously unrealistic, it is an effective and commonly used modeling technique for isolating the proportion of a region's output and employment derived from a specific activity or industry.

In contrast to the social welfare results presented in Chapter 4 of this report, the estimates derived from this analysis represent changes in local output and employment. That is, increases in output in the local economy may reflect a redistribution of spending from another geographic area, not necessarily a net increase in national economic well-being.

Overview of Input/Output Modeling

Industries within a given geographic area are interdependent in the sense that they purchase output from other industries and sectors, and they also supply inputs to other businesses. Thus, the contribution of a particular industry or activity to the regional economy is greater than its individual output. An accounting firm, for example, sells its services to local businesses and individuals and, at the same time, purchases equipment and supplies (e.g., computers) and hires employees with accounting skills. An increase in demand for accounting services will induce an increase in output and employment in related industries. Likewise, a reduction in demand for accounting services will likely have greater regional output and employment effects than just those borne by local accounting firms.

Constructing a regional economic model requires interpretation of the complex relationships between industries. To simplify the analysis, industries that have similar effects on the economy are grouped together in sectors. These sectors are arrayed in an *input/output matrix*, which demonstrates how the input requirements of each sector are fulfilled by output produced in other sectors. This matrix is the source of values known as *multipliers*. Multipliers quantify the relationship between the demand for output from a given sector and the resultant output required of the regional economy. For example, an output multiplier of 1.5 associated with the professional services sector implies that spending of $1.00 for accounting services generates $1.50 in total output by the regional economy (i.e., secondary contributions by office supply firms, the local labor market, and all other sectors).[63] Thus, the estimated contribution of a given sector to the regional economy is ultimately proportional to the size of its multiplier.

Defining the "study area" is an important feature of implementing a regional economic analysis. This area should be drawn broadly enough to include the outer limit of the geographic region through which a change in an activity is expected to reverberate, but not so broadly that impacts become so diffuse as to be indiscernible. Specifically, it should include the actual site of the impact, the regional location of secondary industries similarly affected, the residential location of the labor force and relevant pathways through which goods and services flow.

Overview of the IMPLAN Model

To estimate the regional economic contribution of the horseshoe crab resource, we utilize MicroIMPLAN (IMpact Analysis for PLANning), an input/output model designed by the U.S. Forest Service.[64] Many state and federal planning agencies use IMPLAN for policy planning

[63] The multiplier of 1.5 used in this example implies $1 of primary spending, and $0.5 of secondary spending.

[64] The IMPLAN model is owned and maintained by the Minnesota IMPLAN Group, Inc. (MIG).

and evaluation purposes. The IMPLAN model draws upon data from a number of federal and state entities, including the Bureau of Economic Analysis and the Bureau of Labor Statistics. To group related industries into sectors, IMPLAN utilizes the categories defined by the U.S. Office of Management and Budget's Standard Industrial Classification (SIC) code.

We use IMPLAN to develop three models corresponding to the sectors described above (wildlife viewing/birding, biomedical, and commercial fishing). In each case, we posit a change in output that corresponds to the sector's relative dependence on the horseshoe crab resource. As described previously, we hypothesize this change as a sudden, total absence of the horseshoe crab resource. The model then calculates the corresponding change in demand for inputs to the industries directly affected, changes in output of the secondary industries, and so on. The model traces these changes in demand, output, and employment, which can be classified as *direct*, *indirect*, or *induced*, depending on the source of the change.

- *Direct effects* are changes in production resulting from a change in demand or a supply shock. The modeler specifies these initially.

- *Indirect effects* are changes in production in industries linked to those affected directly. For example, a decrease in biomedical production will decrease demand for laboratory equipment and supplies and thus affect suppliers of those inputs.

- *Induced effects* reflect changes in household consumption resulting from changes in employment brought about by direct and indirect effects. For example, decreased employment in a region may result in decreased consumption of certain services.

These categories are calculated for all industries and aggregated to determine the regional output and employment effects resulting from the posited change in production. Below we present the detailed results of this analysis, after discussing the general limitations of the approach.

Limitations of IMPLAN Analyses

The IMPLAN model estimates only those effects resulting from a specified change at a given point in time, and thus does not account for adjustments that may occur over time. For example, a reduction in local commercial fishing output may encourage suppliers of bait and tackle to diversify their operations and thereby moderate local employment and output losses in that sector. This adjustment would not be reflected in estimates from the model. Furthermore, IMPLAN does not consider the re-employment of workers displaced by the original shift in output and production. As these limitations suggest, net changes in output and employment may be smaller than those estimated by the model, which provides an approximation of regional economic impacts.

An additional limitation of analyses conducted with the IMPLAN model relates to the year of data relied upon. The IMPLAN model uses input/output data from 1994. In this analysis, we rely upon this characterization of the 1994 regional economy to approximate current conditions, as well as economic relationships in the future. This limitation applies to input/output models in general and is not exclusive to the IMPLAN model. Nonetheless, it is important to note that key characteristics of the local economy may change over time, particularly given the sustained economic growth that took place from 1994 to 2000. Given this economic growth, results of this analysis may understate the actual magnitude of regional economic impacts.

Finally, IMPLAN multipliers are designed to take into account the fact that retail sales reflect purchases of wholesale goods by retailers. Often, such purchases are made extra-regionally. As such, it is only the value-added contributed by the local retailer which generates regional economic impacts. To the extent that IMPLAN multipliers under- or overstate actual local value-added for an affected retail sector (e.g., gift shops), the IMPLAN analysis may under- or overestimate regional economic impacts.

MODEL RESULTS BY INDUSTRY

Changes in the regional economies where horseshoe crab-related activities take place would occur if the Atlantic Coast horseshoe crab population (hypothetically) ceased to exist. These changes represent the marginal contribution of the horseshoe crab resource to the economies of these regions. In this section, we consider the magnitude of the changes that would take place under such a scenario, relying on the input/output modeling approach described in the previous section. Specifically, we estimate impacts arising from:

- Changes in local spending by recreational birders viewing the horseshoe crab/shorebird event.
- Changes in output and employment in the (LAL) industry due to the availability of the horseshoe crab for LAL manufacture.
- Changes in local spending by the commercial eel and pot fisheries that utilize horseshoe crab as a key bait source.

Wildlife Viewing/Birding

In this section, we describe our assessment of the regional economic contribution of wildlife viewing/birding activities associated with the annual spring spawning season of the horseshoe crab. For this analysis, the study area constructed consists of Cape May and Cumberland Counties in New Jersey. We designate only this area in southern New Jersey despite the fact that some nascent wildlife viewing/birding activity related to horseshoe crab spawning may be taking place in other regions, such as Port Mahon, Delaware and Monomoy Island, Massachusetts. Whereas the southern New Jersey horseshoe crab/shorebird phenomenon has been well-documented and is clearly causing birders to concentrate in the area each spring, little empirical data or other evidence exist which define the relationships between shorebirds, horseshoe crabs, and bird enthusiasts in other areas.[65] If a true horseshoe crab/shorebird eco-tourism relationship does exist in these areas and birders begin to concentrate for viewing opportunities as a result, then the estimates presented below will constitute a lower bound for the regional economic impacts of birding activities.

As described in Chapter 4, visitation to the New Jersey's Delaware Bayshore is likely to be in the range of 10,000 to 15,000 persons during the horseshoe crab/shorebird season. In accordance with the birding survey results, we assume that this visitation estimate addresses only those visitors for whom viewing the shorebird event constitutes their *primary* purpose for traveling to the region, irrespective of the other recreational attractions located in the vicinity (e.g., Victorian Cape May). Only trips that would otherwise not be taken (but for the horseshoe crab/shorebird event) represent new spending in the region.

Wildlife viewing and birding activities create impacts on regional economies through birders' purchases of goods and services. Estimating the total contribution of these activities requires determining visitors' expenditures (on a per day basis). These estimates, based on 1999 survey results and information provided by local vendors, are provided in Exhibit 5-1.

Exhibit 5-1

ESTIMATED PER-DAY EXPENDITURES FOR THE CAPE MAY HORSESHOE CRAB/SHOREBIRD EVENT

Transportation	$ 12.77
Lodging	$ 44.04
Food	
Groceries	$ 17.19
Restaurants	$ 27.76
Equipment	$ 26.78
Total:	$128.54

Source: IEc analysis of data provided by: Eubanks and Stoll (1999); Cape May Bird Observatory (2000); State of New Jersey (1999).

Birders' per-day expenditures on transportation, food, lodging, and equipment in the region of interest foremost affect businesses within these specific industrial sectors (e.g., hotels, restaurants), but will also support businesses which supply the primary sectors (e.g., food

[65] The State of Delaware, for example, has only recently begun to compile basic statistics on birders visiting Delaware beaches to view migrating shorebirds. According to biologist Alice Doolittle (Delaware Division of Fish and Wildlife), some birders arrive at Port Mahon well before the start of horseshoe crab spawning season. This suggests that shorebirds staging at Port Mahon may not be relying on horseshoe crab eggs as a critical food source. Alternatively, it may be that birders in Delaware have not yet begun to associate shorebird viewing opportunities at Delaware beaches with the arrival of spawning horseshoe crabs.

wholesalers), as well as employees of the primary sector. For example, birders' purchases of scopes and binoculars support local sporting goods stores and gift shops, which in turn support other local businesses through their own purchases and through the purchases of their employees.

To account for expenditures that are made extra-regionally (i.e., outside Cape May and Cumberland Counties), we adjust these estimates of expenditures accordingly. Because survey results indicate that the average distance traveled by recreational birders is over 240 miles, we assume that only one-half of visitors make expenditures on transportation expenses (e.g., gas, tolls) within the study area.[66] Due to limitations in lodging capacity in the Cape May area, we assume 30 percent of birders' stay in hotels, motels, or campgrounds outside the region. Normally, we would also assume some portion of equipment expenditures are made outside the region. Information and opinion provided by equipment vendors in the Cape May vicinity, however, suggest that birders find the horseshoe crab/shorebird event to be so unique and high in quality that they commonly purchase new, higher-grade optics or other equipment (e.g., guidebooks) for the express purpose of experiencing this event. As such, we rely on actual sales data from local retail shops to develop per-day estimates for equipment expenditures and assume that 100 percent of these shops are located within the region.[67, 68]

Applying the per-day expenditures described here to the estimates of visitation, we determine the annual contribution to spending in the Cape May regional economy. Exhibit 5-2 presents the range of results based on these assumptions. The estimates reflect the annual contribution to regional output, employment, and employee compensation of wildlife viewing/birding activities associated with the horseshoe crab/shorebird event.

Exhibit 5-2

ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF HORSESHOE CRAB/SHOREBIRD OPPORTUNITIES

Estimated Number of Annual Trips	Initial Direct Change in Spending Posited in Model (millions of 1999 dollars)	Contribution to Regional Output [a] (millions of 1999 dollars)	Contribution to Regional Employment (persons)	Contribution to Employee Compensation (millions of 1999 dollars)
10,000 to 15,000	$4.6 to $6.9	$6.8 to $10.3	119 to 178	$2.3 to $3.4

Source: IEc IMPLAN analysis.

[a] Output and employee compensation adjusted to 1999 dollars using GDP implicit price deflator (Bureau of Economic Analysis, U.S. Department of Commerce). Includes indirect and induced effects.

[66] Eubanks and Stoll (2000).

[67] Cape May Bird Observatory (January 2000).

[68] Obviously, some or all of this equipment is manufactured and sold by wholesalers located outside the region. IMPLAN multipliers for this type of retail activity attempt to account for the fact that it is only local value-added created by retailers that generates secondary economic effects.

All told, the IMPLAN analysis of wildlife viewing/birding opportunities finds that birders' expenditures on recreation-related goods and services during the horseshoe crab/shorebird season result in a contribution of $6.8 million to $10.3 million per year to the economy of greater Cape May. Similarly, the spending associated with this annual event may contribute 119 to 178 jobs and add $2.3 million to $3.4 million in employee income annually.

Several limitations specific to this IMPLAN analysis of birding activity should be noted. First, they reflect our best estimates of daily expenditures, visitation, and the portion of spending that takes place outside the region. To the extent these estimates vary from actual birder spending, we may overstate or understate actual regional contributions. Second, the results of the regional analysis are subject to similar uncertainties as the welfare analysis contained in Chapter 4. That is, wildlife viewing and birding activities related to the horseshoe crab may be taking place in other regions, but are not captured by this analysis. Thus, we may underestimate total regional contributions of wildlife viewing activities associated with the horseshoe crab by excluding these regions. Finally, it is not known how birders' spending would be affected if the horseshoe crab population suffered a decline, because of the uncertainties surrounding the horseshoe crab/shorebird relationship.

Biomedical (LAL) Industry

In the event that the biomedical firms which manufacture LAL could not secure a steady supply of horseshoe crabs, their contributions to the economies of the regions in which they are located would be minimal.[69] In this section, we evaluate the contributions to regional output, employment, and employee income created by these firms that would not occur but for the horseshoe crab.

Massachusetts

To estimate the contribution of Associates of Cape Cod (ACC), the LAL firm located in Massachusetts, we first estimate the change in regional output, employment, and employee income to the defined study area (Barnstable and Plymouth Counties). This change is simply equivalent to what output, employment, and employee income would be lost but for the availability of the horseshoe crab resource.

To apply the IMPLAN model, we posit that a large portion of LAL manufacturing (and that of related products) would not exist in the absence of a secure supply of horseshoe crab. To translate this change into output estimates for entry into the IMPLAN model, we calculate the output of ACC as a percentage of the entire baseline for biomedical activity located in the region.

[69] Industry representatives assert that while some research and development activities would continue within their LAL divisions in the absence of a secure supply of horseshoe crabs, major LAL manufacturing operations would eventually cease (i.e., after the depletion of inventories).

Results from the IMPLAN analysis indicate the annual contribution to regional output, employment, and employee income associated with ACC's LAL manufacturing activity. Exhibit 5-3 presents these results.

Exhibit 5-3

ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF THE LAL INDUSTRY IN MASSACHUSETTS [a]

Region Included in Model	Initial Direct Change in Spending Posited in Model (millions of 1999 dollars)	Contribution to Regional Output[b] (millions of 1999 dollars)	Contribution to Regional Employment[b] (persons)	Contribution to Employee Compensation (millions of 1999 dollars)
Massachusetts	$14.8 to $19.7	$23.8 to $31.8	144 to 192	$6.2 to $8.3

Source: IEc IMPLAN analysis.
[a] Output and employee compensation adjusted to 1999 dollars using GDP implicit price deflator (Bureau of Economic Analysis, U.S. Department of Commerce).
[b] Contribution to regional output and employment includes indirect and direct effects.

Maryland

The location of BioWhittaker, Incorporated, the LAL manufacturer in Walkersville, Maryland, is a relatively rural area where the local economy is dominated by agricultural activity. Based on this, we assume that BioWhittaker's output constitutes the entire baseline value of the biomedical industry for the specified study area (Howard and Montgomery Counties).[70] However, BioWhittaker is more diversified than the other LAL firms, as it develops and manufactures a variety of other products used in biomedical and pharmaceuticals research and development (e.g., allergy tests). Thus, given that the revenues from LAL manufacture comprise 85 percent of total revenues generated by this firm, we posit an initial change in spending that results solely from the LAL-based portion of BioWhittaker's business.[71] Similar to the IMPLAN analysis for Massachusetts, we assume that most of BioWhittaker's LAL-based output and employment would not exist in the absence of a secure supply of horseshoe crab. Exhibit 5-4 displays the annual contribution to regional output, employment, and employee compensation for the LAL manufacturing in Maryland.

[70] Note that Montgomery County, a highly developed suburb of Washington, D.C., is included in the study area because we assume some of Bio Whittakers' employees reside there.

[71] Based on personal communication with William McCormick, Senior Director, BioWhittaker Incorporated (October 1999).

Exhibit 5-4 ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF THE LAL INDUSTRY IN MARYLAND[a]				
Region Included in Model	**Initial Direct Change in Spending Posited in Model (millions of 1999 dollars)**	**Contribution to Regional Output[b] (millions of 1999 dollars)**	**Contribution to Regional Employment[b] (persons)**	**Contribution to Employee Compensation (millions of 1999 dollars)**
Maryland	$18.7 to $24.6	$26.7 to $34.9	145 to 190	$7.0 to $9.2

Source: IEc IMPLAN analysis.
[a] Output and employee compensation adjusted to 1999 dollars using GDP implicit price deflator (Bureau of Economic Analysis, U.S. Department of Commerce).
[b] Contribution to regional output and employment includes indirect and direct effects.

South Carolina

For Charles River Endosafe, the LAL manufacturer located in Charleston, South Carolina, we define the study area used in this analysis to be Charleston and Colleton Counties. The 1994 baseline data provided by the IMPLAN model, however, show no economic activity in the biomedical industry within this study area. This may simply reflect that Endosafe's activities were not captured in the federal economic statistics on which IMPLAN data are based, or possibly that the firm's revenues are attributed to a parent company located elsewhere.[72] To determine regional economic contribution of the LAL industry in this study area, we adjust these baseline values to account for the presence of Endosafe. We make the assumption that this firm is more or less the same size as the other LAL firms, and that no other significant activity in the biomedical industry exists in this area. Given this, Exhibit 5-5 shows our estimate of the baseline values for output, employment, and employee compensation for the biomedical sector in the South Carolina study area.

Exhibit 5-5 ASSUMED BASELINE VALUES FOR SOUTH CAROLINA BIOMEDICAL (LAL) FIRM[a]	
	Estimate of Baseline Values (millions of 1999 dollars)
Total Firm Output	$60
Employment (persons)	75
Employee Compensation	$10

Source: IEc analysis and industry estimates.
[a] IMPLAN data for baseline values of the South Carolina study area (Charleston and Colleton Counties) reflect no economic activity for the biomedical industry.

[72] Endosafe in South Carolina is owned by Charles River Laboratories, Incorporated, a large biomedical conglomerate headquartered in Massachusetts.

Using IMPLAN to model this regional economy would misrepresent the regional economic contributions made by Endosafe because IMPLAN data show no economic activity occurring in the biomedical sector. Instead of using IMPLAN to estimate regional impacts, we manually calculate the regional economic contribution of the biomedical industry using multipliers from the baseline IMPLAN data for the category containing the biomedical industry. In this analysis, we multiply IMPLAN's output and employment compensation multipliers (1.35 and 1.50, respectively) to the baseline values we assume for these categories. Because IMPLAN does not provide an employment multiplier for the biomedical industry in South Carolina, we assume a value of 2.00 for employment, which approximates the biomedical employment multipliers for the other study areas.

Note that this calculation is essentially the same as those used in the IMPLAN model to produce estimates of region-wide economic changes, so there should be little or no loss in accuracy using this short-cut method. However, a shortcoming of this approach is that it does not provide disaggregated results that show the contribution of the biomedical (LAL) industry to individual industry sectors. Exhibit 5-6 below displays our estimates of annual contribution to regional output, employment, and employee compensation for the South Carolina LAL firm. We cannot estimate the contribution to employment due to the lack of an IMPLAN employment multiplier. Given our assumption of baseline employment in this sector (i.e., 100 persons), however, we anticipate that the employment contribution for the South Carolina study area would be similar to that in other regions (e.g., 150 to 200 persons).

Exhibit 5-6

ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF THE LAL INDUSTRY IN SOUTH CAROLINA[a]

Region Included in Model	Initial Direct Change in Spending Posited in Model (millions of 1999 dollars)	Contribution to Regional Output (millions of 1999 dollars)	Contribution to Regional Employment (persons)	Contribution to Employee Compensation (millions of 1999 dollars)
South Carolina	$16.0 to $19.3	$22.2 to $29.3	150	$4.9 to $8.1

Source: IEc IMPLAN analysis; IEc baseline assumptions.
IMPLAN baseline data for the South Carolina study area reflect no economic activity for the biomedical industry. These results are based on adjustments to the baseline values to account for the presence of Endosafe in Charleston, SC, the application of IMPLAN's multipliers for output and employee compensation, and our assumed multiplier for employment.

a Output and employee compensation adjusted to 1999 dollars using GDP implicit price deflator (Bureau of Economic Analysis, U.S. Department of Commerce). Output and employment estimates include indirect and induced effects, as well as direct effects.

Limitations and Uncertainties

We point out a few key caveats or limitations associated with this analysis of the contributions of the biomedical (LAL) industry to the regions in which major firms reside. These include the following:

- **Role of horseshoe crab in LAL production.** This analysis makes an assumption that the output of LAL manufacturers effectively ceases in the absence of the Atlantic coast horseshoe crab population. In reality, these firms may make adjustments that are not accounted for here, especially if they are capable of adapting their manufacturing operations to utilize a substance other than horseshoe crab blood. However, it is not clear that these firms and locations would dominate the market for substitutes.

- **Definition of study area.** LAL firms are located in or proximate to coastal areas which are also characterized by significant economic activity. Thus, these results are highly sensitive to the definition of the study area used in each model. As such, the inclusion (or exclusion) of even one county in a study area will influence the relative contribution of the LAL industry. For example, the value of total baseline output for the Maryland study area, including both Howard and Montgomery Counties, is $54 billion. Excluding Montgomery County (which extends from Howard County to the Washington, D.C. border) from this study area would reduce the value of baseline output for this study area to $10 billion.[73]

Commercial Fishing

In the sections below, we describe the regional economic contributions of the whelk and eel pot fisheries. To model the contributions of these industries, we use IMPLAN to project the impact of a (hypothetical) absence of horseshoe crab bait on the level of economic activity in the whelk and eel pot fisheries.

Whelk Pot Fishery

In this analysis of the whelk pot fishery, we examine the economic contribution of commercial whelk potting to regional communities along the Atlantic Coast. As a first step, we identify appropriate study areas for inclusion in the IMPLAN model. As mentioned in Chapter 4, commercial whelk potting takes places in broad coastal areas from Massachusetts to the Carolinas. In order to realistically model contributions to regional economies, however, we focus only on areas where a significant level of whelk potting occurs and/or areas where enterprises which support whelk potting reside.[74] For example, study areas selected for this

[73] We include Montgomery County in the study area because some of BioWhittaker's employees reside there.

[74] Our selection of study areas is primarily based on information from industry contacts in each state indicating the common locations for commercial whelk pot fishing.

analysis generally include the location of marinas out of which fishermen operate, as well as the location of service industries such as boat repair, fuel, and ice production. Exhibit 5-7 lists the areas selected.[75]

Exhibit 5-7

STUDY AREAS USED IN REGIONAL ECONOMIC ANALYSIS OF THE WHELK POT FISHERY

Study Area	State(s)	Counties
1	Massachusetts	Barnstable, Plymouth, Dukes
2	Rhode Island; Connecticut	Washington, Kent (RI); New London (CT)
3	New York	Suffolk
4	New Jersey; Delaware; Maryland	Cape May, Cumberland (NJ); Kent, Sussex (DE); Worcester (MD)
5	Virginia	Accomack, Northampton, Hampton

To apply the IMPLAN model, we posit that activity in the whelk pot fishery would substantially decrease given a hypothetical absence of horseshoe crab bait. To translate this change in activity to an input for use in IMPLAN, we calculate the economic output of whelk potting in each study area as a percentage of the total baseline commercial fishing activity in the study area. This requires estimation of the current size of the whelk pot fishery in each area. Using the methodology outlined in Chapter 4 for determining the total size of the whelk pot fishery, we calculate the annual quantity of potted whelk landed in each state.[76] Based on these state landings, we then derive estimates of the annual revenue attributable to the sale of whelk landings.[77] We attribute the total landings and revenue for each state to the corresponding study area. For example, we apply all whelk pot landings and revenue for Massachusetts to Study Area 1 and apply all landings and revenue estimates for Rhode Island and Connecticut to Study Area 2.

To run IMPLAN, we posit two scenarios by varying the economic importance of whelk potting in each study area. In the first, we assume that although horseshoe crab is the primary bait source for whelk pot fishermen, methods of bait extension or substitute baits reduce some fishermen's demand for horseshoe crab.[78] As such, we posit that 65 percent of whelk pot

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[75] Note that study areas vary significantly in total geographic size and number of counties. They represent our understanding of those regions where impacts to the whelk pot fishery would reverberate in the economy without being so broad as to be indiscernible. We acknowledge that these study areas exclude some regions where whelk potting occurs, but we believe the economic contribution of whelk potting and supporting industries in these other regions to be minimal.

[76] For a detailed description of the methodology used to estimate these quantities, see Chapter 4.

[77] A comprehensive table listing our estimates of annual landings and revenues by state is contained in Appendix 5-A.

[78] Methods used to extend the useful life of horseshoe crab bait currently being investigated include: (1) the use of smaller pieces of horseshoe crab with other "binder baits"; and (2) bait bags, which protect the horseshoe crab bait from small marine predators.

fishermen would be impacted by a significant change in the supply of horseshoe crabs. In the second scenario, we assume that whelk potting would essentially disappear given a change in the supply of horseshoe crabs. As result, we posit a 95 percent change in whelk potting activity. The range of results from the IMPLAN analysis represents the lower and higher bound estimates that correspond to these two scenarios. Exhibit 5-8 below displays our results.

As shown in Exhibit 5-8, these results suggest that the Virginia study area receives the largest economic contribution from the whelk pot fishery. Each year, between $4.0 million and $5.5 million in economic output and between 160 to 217 jobs accrue to Accomack, Northampton, and Hampton counties from commercial whelk potting.

MODELING "DOWNSTREAM" BENEFITS OF THE WHELK POT FISHERY

The IMPLAN model relies on multipliers that quantify relationships between industries in a geographic region. IMPLAN, however, only models those relationships *upstream* in the economy, that is, industries that provide inputs to the industry of interest. In this case, the model excludes from consideration the contribution of whelk pot fishing to industries and services that rely on the output from whelk pot fishing as input to their industry. These are known as *downstream* industries. As a result, this analysis does not account for the dependence of whelk processors on the whelk pot fishery.

We lack adequate data for all Atlantic coast whelk processors to permit a comprehensive industry analysis in IMPLAN. Moreover, the percent of total seafood processing attributable to whelk varies significantly from one processor to another, as many operations process other fish and shellfish in addition to whelk. As an example of the contribution provided to regional economies by whelk processors, we run IMPLAN analyses for two well-known commercial whelk processing operations. In the case of both processors, our information indicates that whelk comprises all or almost all of their seafood processing. As such, we posit that, but for the presence of the horseshoe crabs, these processors would disappear. Our IMPLAN analyses provided the following results for these downstream industries.

CONTRIBUTION TO REGIONAL ECONOMIES PROVIDED PROVIDED BY TWO WHELK PROCESSORS[a]

Processor - County	Baseline Regional Economic Output (millions of dollars 1999)	Baseline Regional Employment (persons)	Initial Change in Output Posited in Model (millions of 1999 dollars)	Contribution to Regional Output (millions of 1999 dollars)	Contribution to Regional Employment (persons)
1 - Bristol, MA	$19,562.0	239,893	$1.6	$2.8	25
2 - Hampton, VA	$4,714.5	78,411	$2.1	$2.7	23

[a] Note that, because the IMPLAN model includes linkages from downstream processors to the upstream fishermen who supply them (but not visa versa), adding these estimates to totals from the Whelk fishing regional model would result in some double-counting.

We estimate that these two whelk processors contribute approximately $2.8 million and $2.7 million to regional economic output, and approximately 25 and 23 persons to regional employment.

Exhibit 5-8

ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF THE ATLANTIC COAST WHELK POT FISHERY

Study Area	State (Counties)	Initial Direct Change in Output Posited in Model (millions of 1999 dollars)		Contribution to Regional Output (millions of 1999 dollars) [a]		Contribution to Regional Employment (persons)		Contribution to Employee Compensation (millions of 1999 dollars)[b]	
		Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
1	**Massachusetts** (Barnstable, Plymouth, and Dukes)	$2.3	$3.2	$3.2	$4.3	45	61	$0.6	$0.8
2	**Rhode Island** (Washington, Kent) **Connecticut** (New London)	$0.4	$0.5	$0.5	$0.7	6	8	$0.1	$0.1
3	**New York** (Suffolk)	$1.2	$1.6	$1.7	$2.2	37	51	$0.3	$0.4
4	**New Jersey** (Cape May, Cumberland) **Delaware** (Kent, Sussex) **Maryland** (Worcester)	$1.2	$1.6	$1.5	$2.1	24	33	$0.3	$0.3
5	**Virginia** (Accomack, Northampton, Hampton)	$2.9	$4.0	$4.0	$5.5	160	217	$0.6	$0.8
TOTAL		**$8.0**	**$10.9**	**$10.9**	**$14.8**	**272**	**370**	**$1.9**	**$2.4**

[a] Dollar values were adjusted to 1999 dollars using the GDP implicit price deflator (Bureau of Economic Analysis, U.S. Department of Commerce). Output on and employment estimates include indirect and induced effects, as well as direct effects.

[b] It is important to note that employee compensation represents a component of the change in output.

Source: IEc IMPLAN Analysis.

Eel Pot Fishery

Our analysis of the regional economic contributions of the eel pot fishery employs a similar approach to our analysis of commercial whelk potting. First, we identify study areas that best describe the economic activities involved in eel potting. Commercial eel potting occurs in coastal watersheds and freshwater tributaries from Maine to Florida, and every Atlantic coastal state reports landings for potted eel. To assess only that portion of the eel pot fishery dependent upon horseshoe crab bait, we select six study areas for inclusion in IMPLAN based on economic linkages between regions and consistent use of horseshoe crab bait. As eels are catadromous, the study areas for the eel pot fishery include coastal counties, as well as inland counties with significant freshwater tributaries. The six study areas selected in this analysis are listed below in Exhibit 5-9.[79]

Exhibit 5-9

STUDY AREAS USED IN REGIONAL ECONOMIC ANALYSIS OF THE EEL POT FISHERY

Study Area	State(s)	Counties
1	Massachusetts	Essex
2	Rhode Island; Connecticut	Kent, Washington (RI); Middlesex (CT)
3	New York	Suffolk
4	New Jersey; Delaware; Maryland	Cumberland, Burlington (NJ); Kent, Sussex (DE); Somerset, Wicomico (MD)
5	Virginia	Westmoreland, Middlesex, Gloucester
6	Florida	Clay, Putnam

Similar to our analysis of the whelk pot fishery, we assume that a hypothetical absence of horseshoe crab bait would affect eel potting activity in each study area. In order to posit the resultant change in eel potting for input into IMPLAN, we first estimate the economic output of eel potting in each study area. Based on the methodology and landings estimates described in Chapter 4, we estimate the total annual quantity and revenues for horseshoe crab-dependent eel pot landings in each state.[80] For each state, we assign the landings and revenue to the study area

[79] Note that study areas vary significantly in total geographic size and number of counties. Despite these differences across study areas, they represent our best estimates of regions in which changes to the eel pot fishery would reverberate without being dispersed so broadly as to be undetectable. In addition, we realize that these study areas exclude some regions where eel potting occurs. We exclude from our analysis any states for which we determined that eel pot landings from horseshoe crab bait were minimal. These states include Maine, New Hampshire, North Carolina, South Carolina, and Georgia.

[80] For a detailed description of the methodology used to estimate these quantities, see Chapter 4. For our estimates of annual landings and revenue of potted eel by state, refer to Appendix 5-B.

that falls within its boundary. For example, we apply all eel pot landings and revenue for Massachusetts to Study Area 1 and apply all landings and revenue estimates for Rhode Island and Connecticut to Study Area 2.

We run the IMPLAN model by positing a change to eel potting activity in each study area. Given the hypothetical absence of the horseshoe crab, we assume that a 50 percent reduction in eel potting activity would result. We posit only a partial decline because horseshoe crabs are not the sole bait for potting eel. We assume many fishermen would continue to pot for eel using other bait. Based on these assumptions, IMPLAN provides estimates of the total contribution to economic output, employment, and employee compensation attributable to eel potting with horseshoe crab bait. Exhibit 5-10 displays these results.

Exhibit 5-10

ANNUAL REGIONAL ECONOMIC CONTRIBUTION OF THE AMERICAN EEL POT FISHERY

Study Area	State (Counties)	Initial Change in Output Posited in Model (thousands of 1999 dollars)[a]	Contribution to Regional Output (thousands of 1999 dollars)	Contribution to Regional Employment (persons)	Contribution to Employee Compensation (thousands of 1999 dollars)[b]
1	**Massachusetts** (Essex)	$212.7	$300.8	4	$56.5
2	**Rhode Island** (Washington, Kent) **Connecticut** (Middlesex)	$71.6	$98.8	1	$18.9
3	**New York** (Suffolk)	$187.4	$269.5	6	$48.1
4	**New Jersey** (Cumberland, Burlington;) **Delaware** (Kent, Sussex) **Maryland** (Somerset, Wicomico)	$444.2	$663.6	22	$103.9
5	**Virginia** (Westmoreland, Middlesex, Gloucester)	$552.8	$732.0	30	$98.4
6	**Florida** (Clay, Putnam)	$167.1	$231.7	8	$33.8
TOTAL		**$1,635.8**	**$2,296.4**	**71**	**$359.6**

[a] Dollar values were adjusted to 1999 dollars using the GDP implicit price deflator (Bureau of Economic Analysis U.S. Department of Commerce). Output and employment estimates include indirect and induced effects, as well as direct effects.

[b] It is important to note that employee compensation represents a component of the change in output.

Source: IEc IMPLAN Analysis.

As shown in Exhibit 5-10, we estimate that eel potting contributes the most to the Mid-Atlantic region and Virginia. The total estimated contribution to annual regional output in New Jersey, Delaware, and Maryland is $663,600, while eel potting in Virginia contributes $732,000 annually. Similarly, approximately 22 jobs accrue to New Jersey, Delaware, and Maryland, and 30 jobs accrue annually to Virginia due to commercial eel potting.

Limitations and Uncertainties

To provide context for interpretation of our results, we present below uncertainties and caveats associated with our regional economic analysis of commercial fishing.

- **Assumption of bait use.** For both commercial fishing analyses, we rely on assumptions about fishermens' dependence on horseshoe crab bait. These assumptions are based on qualitative information provided to us by whelk and eel potters and state fisheries management staff. They represent best estimates, but to the extent that fishermen rely on horseshoe crabs more or less than we assume, our analysis may underestimate or overestimate the total contribution to commercial fishing of horseshoe crab bait. In addition, our analysis does not account for potential changes in the demand for horseshoe crab bait in the future.

- **Information sources.** Given the lack of available data on both the whelk and eel pot fisheries, we rely almost entirely on expert opinion and judgment to develop our analyses. We use input from industry contacts to perform calculations that contain uncertainties at many points. As such, our results are highly sensitive to the validity of information provided to us by industry contacts.

- **Definition of study areas.** The results of our analyses are highly sensitive to our definition of appropriate study areas for each fishery. We define the study areas according to our knowledge of the fisheries and IMPLAN, but our results are significantly affected by inclusion or exclusion of areas with sizeable economic activity.

SUMMARY AND CONCLUSIONS

Major economic activities which depend on the horseshoe crab -- wildlife viewing/birding, LAL manufacturing, and eel and conch pot fishing -- create various "ripple" effects on the regional economies of the Atlantic Coast. The results of the IMPLAN analysis of these contributions are summarized in Exhibit 5-11 below.

Exhibit 5-11

SUMMARY OF RESULTS

Industry/ User Group	**REGIONAL ECONOMIC CONTRIBUTIONS** ***(affected region)***
WildlifeViewing/ Birding	• $6.8 million to $10.3 million; 119 to 178 jobs (New Jersey)
Biomedical (LAL) Industry	• $23.8 million to $31.8 million; 144 to 192 jobs (Massachusetts) • $26.7 million to $34.9 million; 145 to 190 jobs (Maryland) • $22.2 million to $29.3 million; approximately 150 jobs (S. Carolina)
Whelk Pot Fishery	• $3.2 million to $4.3 million; 45 to 61 jobs (Massachusetts) • $0.5 million to $0.7 million; 6 to 8 jobs (Rhode Island and Connecticut) • $1.7 million to $2.2 million; 37 to 51 jobs (New York) • $1.5 million to $2.1 million; 25 to 33 jobs (New Jersey, Delaware, Maryland) • $4.0 million to $5.5 million; 160 to 217 jobs (Virginia)
Eel Pot Fishery	• $0.3 million; 4 jobs (Massachusetts) • $0.1 million; 1 job (Rhode Island, Connecticut) • $0.3 million; 6 jobs (New York) • $0.7 million; 22 jobs (New Jersey, Delaware, Maryland) • $0.7 million; 30 jobs (Virginia) • $0.2 million; 8 jobs (Florida)
TOTALS	• **$92.7 million to $123.4 million; 900 to 1,150 jobs.**

As noted earlier in this chapter, certain caveats apply to results generated using the IMPLAN model. First, a general limitation of the IMPLAN model is its reliance on 1994 economic data. In light of the rate of economic growth in the last five years, this data is likely to understate the level of baseline economic activity in all regions, particularly in fast-growing coastal regions. Second, IMPLAN is not a dynamic modeling tool and does not account for "feedback" effects in the economy (i.e., adjustments that take place over time). As such, actual changes in output and employment may be smaller, in relative terms, than those estimated by the model. Third, implicit to the multipliers employed by IMPLAN to model direct, indirect, and induced effects are certain assumptions regarding the local contributions to "value-added" for various industry sectors. IMPLAN results for the retail sector, for example, are especially sensitive to the assumed multiplier values, as local value-added content for this economic sector can vary widely depending on the regional manufacturing base. Where multipliers do not reflect actual local value-added content in goods and services, IMPLAN results may be somewhat biased.

With respect to this specific application of the IMPLAN model, we find that the definition of the *study area* (i.e., the localities that make up each region) is the most significant caveat. Examples described in this analysis show that relative regional contributions to output and employment may change somewhat if key municipalities are included (or excluded) from the model. Based on our research, however, the study areas selected for inclusion in this regional assessment reflect best estimates of actual economic interdependencies that exist between these industries and the regions in which they are located.

APPENDICES

Appendix 5-A

ESTIMATED 1998 LANDINGS AND REVENUE FOR THE WHELK POT FISHERY[a]

State[b]	Landings (pounds in-shell)	Revenue (dollars)[c]
Massachusetts	3,877,407	$3,489,666
Rhode Island	387,741	$348,967
Connecticut	290,806	$261,725
New York	1,938,703	$1,744,833
New Jersey	387,741	$348,967
Delaware	969,352	$872,417
Maryland	581,611	$523,450
Virginia	4,652,888	$4,187,599
North Carolina	145,403	$130,862
South Carolina	145,403	$130,862
TOTAL	**13,377,054**	**$12,039,348**

[a] Calculated by taking: [(Number of Conch Boats x for Annual Yield Per Boat) x the Average Price per Pound].

[b] State fisheries management personnel in Maine, New Hampshire, Georgia, and Florida reported no commercial landings for potted whelk. State contacts in North Carolina and South Carolina reported whelk pot landings that were small enough to warrant exclusion from the regional analysis using IMPLAN.

[c] Calculated using $0.90 per pound of whelk (in-shell). This price represents the average of several market prices provided to us by fishermen, processors, and state fisheries management contacts.

Appendix 5-B

ESTIMATED 1998 EEL POT LANDINGS AND REVENUE ATTRIBUTABLE TO HORSESHOE CRAB BAIT[a]

State[b]	Landings (pounds in-shell)	Revenue (dollars)[c]
Maine	7,540	$15,268
New Hampshire	112	$226
Massachusetts	223,404	$452,394
Rhode Island	55,851	$113,098
Connecticut	19,315	$39,113
New York	196,854	$398,629
New Jersey	134,856	$273,083
Delaware	267,881	$542,458
Maryland	63,926	$129,450
Virginia	567,279	$1,148,740
North Carolina	13,424	$27,184
South Carolina	--	--
Georgia	--	--
Florida	175,000	$354,375
TOTAL	**1,725,442**	**$3,494,018**

[a] Calculated by applying estimates of the number of eel potters per state (derived from ASMFC 1998 horseshoe crab landings) to the following: [(Number of Eel Potters x Annual Yield Per Boat) x the Average Price per Pound].

[b] States with no estimated landings from eel potting represent states for which no horseshoe crab landings were provided. As a result, we had no basis for estimating the number of eel potters in the state.

[c] Calculated using $2.03 per pound of eel landed, which represents the average of estimates (consumption and bait) provided to us by fishermen and state fisheries management staff.

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